

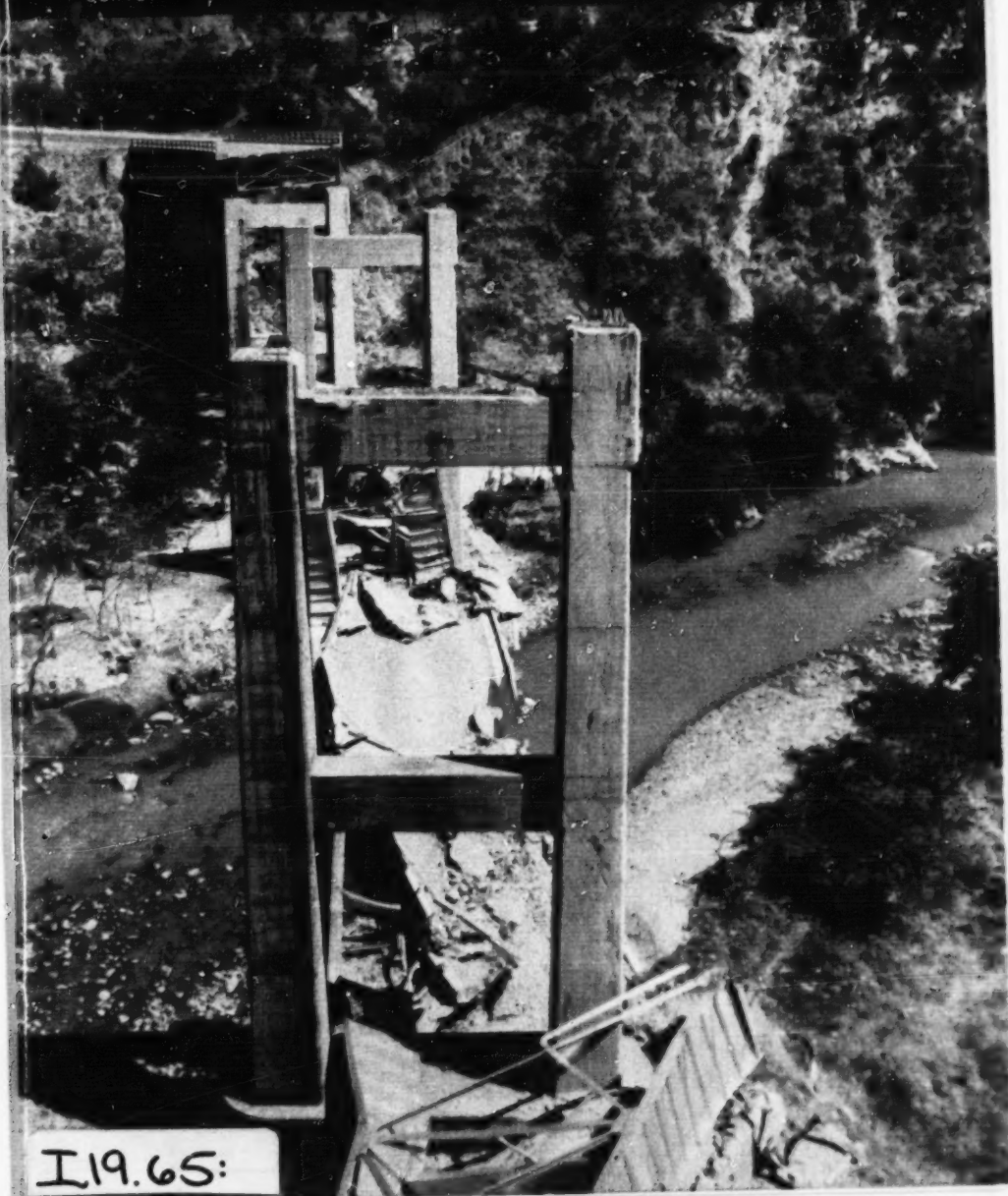
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UNITED STATES
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GEOLOGICAL
SURVEY

Earthquake Information Bulletin

January-February 1982, Volume 14, Number 1



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INTERIOR**

JAMES G. WATT, Secretary

**GEOLOGICAL SURVEY
Dallas L. Peck, Director**

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Cover: Collapse of the three central spans of the Agua Caliente Bridge during the 1976 Guatemala earthquake. (Photograph by A. F. Espinosa.)

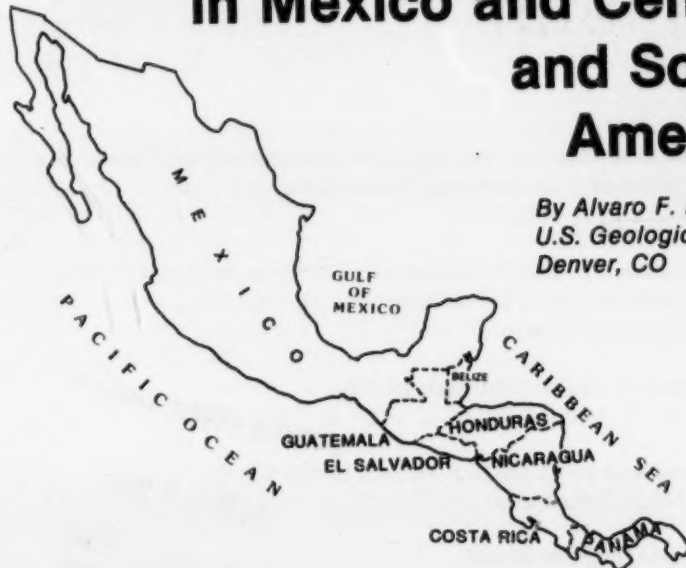
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Introduction: Seismology and Earthquake Engineering in Mexico and Central and South America

By Alvaro F. Espinosa,
U.S. Geological Survey,
Denver, CO



The headlines of the February 4, 1976, morning paper read "Guatemala struck by a severe earthquake; 10,000 killed, 50,000 injured, thousands homeless." This Guatemalan earthquake, with a surface-wave magnitude of 7.5, claimed 22,700 lives, injured more than 76,000 people, and left more than 1 million people homeless; the estimated losses were in the \$1.1 billion range. On July 27, 1976, a very severe earthquake, with a surface-wave magnitude of 7.9, occurred east of Beijing (Peking) in northeast China and claimed the lives of perhaps 500,000 people. This earthquake was one of the greatest natural disasters of this century. On October 10, 1980, an earthquake, with a surface-wave magnitude of 7.3, occurred in Algeria. This earthquake caused extensive damage,

claiming more than 5,000 lives, injuring more than 9,000 people, and leaving over 200,000 people homeless; unsafe buildings, urban congestion, and poor soil conditions were some of the reasons for the loss of life.

Earthquake hazards have affected the lives of many people throughout the world. Earthquakes have no international boundaries. They will continue to take place as they have throughout the centuries. It is difficult to ignore earthquakes and the damage and losses brought by these natural events. It is also difficult to remain unaware of the increased exposure of society to earthquake hazards and, in particular, the threat to urban areas in earthquake-prone regions of the world. The inherent international nature of seismology reflects the common objec-

tive of studies of earthquake hazards mitigation, namely to reduce human suffering.

The principal hazard to life from earthquakes is the collapse of man-made structures which is due to ground shaking. There are other serious earthquake hazards, such as landslides, breakage along active faults, soil failure, liquefaction, and so forth, which can interrupt lifelines, in particular, roads, railroads, and communication networks. Some of these earthquake hazards can dam streams and cause lakes that are suddenly released when the dam fails.

This issue of the *Earthquake Information Bulletin*, the first of two such issues, reports the state-of-the-art in seismology and earthquake engineering that is being advanced by our colleagues in Central and South America and in Mexico. The issue provides basic information on seismological station locations in Latin America and some of the programs in strong-motion seismology, as well as some of the organizations involved in these activities.

These studies are similar in scope to programs being undertaken by the U.S. Geological Survey. The common objective is to reduce earthquake hazards. There are many ways of mitigating losses. The principal approaches are through studies aimed at identifying the seismic risk in earthquake prone regions and through studies that will in the near future make earthquake prediction a reality. To perform these types of research, a multidisciplinary effort is needed; it is necessary to involve scientists in a variety of fields in the earth sciences and in engineering. The outcome of these studies is applied research that will eventually assist the urban planner, public officials at the Federal, State, and local levels, and the concerned citizen to become more aware of the effects of

past—and future—earthquakes and the methodology that should be followed to minimize loss of life and damage to manmade structures.

The world's earthquakes are not randomly distributed around the Earth. There is a definite order to the distribution of seismic activity. World seismicity is concentrated in narrow zones which delineate the boundaries of the thick plates of the Earth's outer crust which are in constant motion. Where these plates interact, important geologic processes are taking place. There are 13 major plates and a dozen or so smaller plates; their pattern is neither symmetrical or simple. Because of the global interaction of these plates, there is constant seismicity on our planet Earth; the Americas are an arena of high seismic and volcanic activity. Plate tectonics is a dynamic phenomenon which has been going on for millions of years and will continue. We on Earth will always be subject to the effects of earthquakes.

We have learned a great deal about the Earth's interior from seismology, and we have used seismology to learn about the interior of the Moon (selenology). It is through research in seismology that we have been able to identify the different crustal plates on the Earth's surface. By knowing the seismicity of the Earth instrumentally and historically, we have been able to provide valuable information in the evaluation of seismic hazards. Furthermore, we have been able to use this knowledge in aiding the engineer in his quest for better construction practices. Through this process, we can expect to mitigate loss of lives and economic losses incurred by destructive earthquakes.

We should also remember that earthquakes do not need to be large to be destructive. The 1963 Skopje earthquake in Yugoslavia, with only a moderate surface-wave magnitude of



6.0, damaged 10 percent of the buildings in that city, and about 60 percent of the other buildings sustained damage beyond repair. The Morocco earthquake of 1960, with a magnitude of 5.5, caused severe damage to the city of Agadir. The Caracas earthquake, in Venezuela, in 1967, with a magnitude of 6.3, caused extensive damage to Caracas and to the northern coastal region of Venezuela, as well as claiming numerous lives. The San Fernando Valley, Calif., earthquake of February 1971, with a magnitude of 6.4, is another example of an earthquake of moderate magnitude with damaging effects. The Managua, Nicaragua, earthquake of December 1972, with a moderate 6.2 magnitude, claimed numerous lives and caused extensive

damage to Managua. Many more examples exist of moderate earthquakes which have caused extensive damage. They illustrate the problem of earthquakes that occur near congested urban areas and cause severe damage to the economy and welfare of the country.

The results from seismological studies that are used by the engineering community are just one of the benefits obtained from research aimed at mitigating the earthquake hazard. In this issue, some of our Latin American colleagues describe their current programs in seismology and earthquake engineering, their local seismic networks, some of their future plans, and some of the cooperative programs with different international organizations.

The Role of the Organization of American States in the Development of Seismology in Latin America

*By Antonio Quesada,
Organization of American States,
Washington, DC*

Seismological studies in Latin America were initiated at the beginning of the 20th century, when the first seismological stations were deployed by certain scientific associations. These efforts provided an incentive to the professional community for further activities. Until this date, the only seismic records that existed were historical accounts of catastrophes caused by earthquakes and volcanic eruptions. This type of information, of course, leads to "fantasy" and incorrect descriptions of what has taken place.

During the years 1930-60, seismological stations were developed in Argentina, Chile, Colombia, Mexico, Peru, and Venezuela. This step forward allowed the production of seismological bulletins; these were used by a few seismologists and by some civil engineers to perform the first studies in seismic-risk evaluation and to apply the knowledge to building construction.

In 1970, the Organization of American States (OAS), through the Regional Program of Scientific and Technological Development, made a detailed analysis of the field of seismology and its disciplines in Latin America. They evaluated the importance and impact of these subjects on

the mitigation of seismic hazards in those regions of Latin America which are prone to earthquake activity. From this study, it was concluded that most of Latin America had an immediate need to improve the number of qualified personnel working in this field. Furthermore, the study pointed out the need to develop programs in applied seismology and in earthquake engineering and the urgency to amplify and strengthen the existing centers of higher education specializing in seismology.

Through these efforts, in June 1970, under the OAS Multinational Program in the Earth Sciences, courses at the graduate and postgraduate level were initiated in seismology and geophysics at the Department of Geophysics and Geodesy of the University of Chile and at the Geophysics Institute of the National University of Mexico (UNAM). Nine scholarships were granted to each center for Latin American applicants.

In 1972, the Instituto de Materiales y Modelos Estructurales of the Central University of Venezuela was integrated into the OAS Multinational Program. In 1973, under the auspices of OAS, the first courses in earthquake engineering were offered, and 12 scholarships were awarded. Concurrently, this program was extended to incorporate the Geophysical Institute of Peru and the Seismology Department of the University of the West Indies. These two

centers are dedicated to seismological and volcanological research.

Also in 1973, because of the 1972 destructive earthquake in Nicaragua, the OAS Multination Program, in collaboration with the U.S. Agency for International Development, assisted in the organization and implementation of a new Seismic Research Institute in Nicaragua and also assisted in the process of providing instruments and training to this new organization.

The training of personnel in these institutions has motivated the OAS Multinational Program to extend its technical assistance to other centers in Latin America, such as Observatorio San Calixto, La Paz, Bolivia; the Geophysical Observatory of the Colombian Andes, Bogotá, Colombia; Quito Observatory of the Polytechnic University of Quito, Quito, Ecuador; and the Central-American Geological School, San José, Costa Rica. To the first three centers, the OAS granted assistance-in-aid to have new seismological stations closely consulting with the Geophysical Institute of Peru. In Costa Rica, the OAS, with the technical assistance from UNAM and the U.S. Geological Survey, assisted in the creation of a new Geophysics and Volcanology Department.

Through the years, the OAS has sponsored a number of activities in Latin America, for instance:

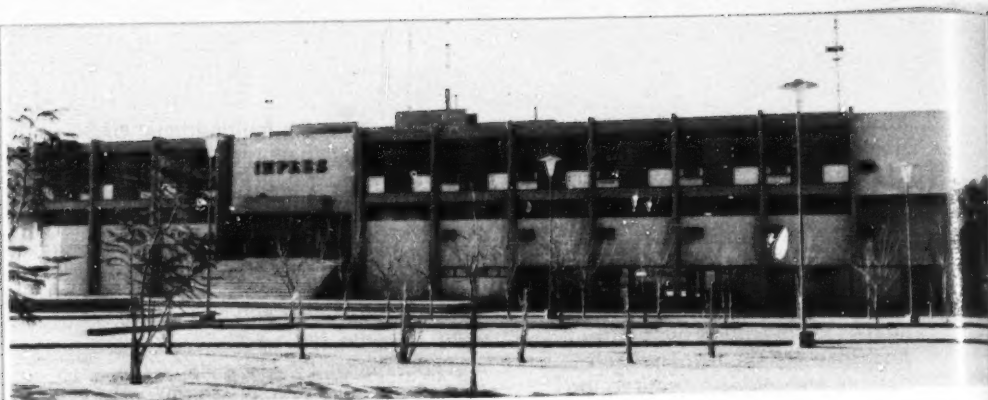
- Granting scholarship and fellowships for M.S. and Ph. D. programs.
- Interchange of technical and scientific personnel in Latin America.
- Visiting professor programs.
- Training programs for technicians.
- Granting funds to procure strong-motion instruments for engineering studies.
- Granting funds to procure seismological stations.
- Sponsoring numerous workshops.
- Sponsoring numerous seminars about seismology and earthquake engineering.
- Sponsoring a number of postearthquake activities after destructive earthquakes have devastated urban areas in Latin America.
- Sponsoring and disseminating scientific information with the objective of mitigating earthquake damage and loss.

The OAS is involved at present with some multinational projects in Latin America; for instance, the Andean Seismic Protection Project (PROSISAN I) which deals with seismic protection in the Andes. The participant countries are as follows: Peru, Ecuador, Colombia, and Venezuela; the Geophysical Institute of Peru serves as the coordinator for this project. Another ongoing project is between Mexico and Venezuela and is Seismic Risk Evaluation. PROSISAN (II) involves seismic hazards studies in Latin America involving Chile and Argentina. Other activities, such as pilot studies for given regions in Latin America, are planned and executed through OAS assistance to countries prone to earthquake activity. The OAS collaborates with other international agencies such as the Canadian International Development Agency (CIDA), United Nations Disaster Research Organization, and the U.S. Geological Survey in postearthquake studies and pilot studies on seismograph deployment. The OAS has been instrumental in motivating local investigators and Latin American government officials to reexamine and improve their seismic building codes.

The OAS has maintained information links among research centers and government offices involved in the decisionmaking process; it has served as a liaison in the interchange of information and technology at the regional

level. The OAS encouraged the formation of the Latin American Association of Engineering Seismology during the Second Latin American Seminary in Earthquake Engineering which took place in Caracas, Venezuela, in 1979. This Association provides an opportunity for the interchange and discussion of ideas among our Latin American colleagues. The recommendations and improvements to the seismic building code and adequate procedures for construction practices are just a few examples of the topics being considered by the Association.

Details about the multinational OAS-funded programs are discussed by some of the contributors in this volume. The OAS continues to encourage the development of seismology in Latin America, and it hopes to see a better exchange of scientific personnel and projects in the years to come. Latin America presents a unique opportunity for seismological study because it is a natural laboratory which allows us to advance and understand the phenomenon of earthquakes.



National Institute of Seismic Mitigation, San Juan, Argentina.

Seismic Prevention in Argentina

*By Julio S. Aguirre Ruiz
and Juan C. Castano,
National Institute of Seismic
Prevention, San Juan, Argentina*

Introduction

The history of seismic studies in Argentina dates back to the middle of the 19th century. The first earthquake which provided valuable information was the one which destroyed the city of Mendoza on March 10, 1861 ($M_s = 7.5$). About 8,000 of the 113,000 inhabitants perished as a result of the earthquake. Since then, numerous earthquakes have been studied. Some of the strongest which stand out because of their destructive effects are as follows:

- San Juan-La Rioja earthquake on October 27, 1894 ($M_s = 8.0$).
- San Juan earthquake on January 15, 1944 ($M_s = 7.8$).
- Salta earthquake on August 25, 1948 ($M_s = 7.0$).

- Caucete, San Juan Province, earthquake on November 23, 1977 ($M_s = 7.4$).

The earthquake which destroyed the entire city of San Juan on January 15, 1944, was of great significance to our Republic. Ten thousand people perished that evening, and it was because of this devastating event that the Federal authorities created a national institution with the sole aim of planning and carrying out the reconstruction of the destroyed city. The reconstruction process dictated that special regulations for earthquake-resistant structures had to be developed. The present city of San Juan was rebuilt taking into account a new building code which was rigorously applied and checked by the local authorities. Thus, the National Institute of Seismic Mitigation—INPRES—was born. Later, the Argentine Government decided to make available the benefits derived from this organization to all the national territory.

INPRES has the responsibility for a national plan of seismic-hazard mitigation. It also has the important task of promoting and coordinating research studies which will evaluate seismic hazards and mitigation. This process is achieved through regulations which serve to guarantee the stability of structures and code requirements that depend on the government for enforcement.

Description of INPRES

INPRES is part of the Ministry of Public Works of Argentina. It was created on May 8, 1972, and is located in the city of San Juan. Its duties and objectives are to:

- Provide earthquake-resistant regulations that will be compulsory throughout the Argentine territory.
- Evaluate the seismicity and the seismic risk throughout the national territory.
- Plan, build, and operate the National Seismological Network and the National Network of Accelerographs and Seismoscopes.
- Install and operate the Central Laboratory of Earthquake Resistant Construction, Structures, Materials Testing, and Geotechniques.
- Act as an official representative with regard to all national and international organizations with earthquake engineering and seismology.
- Act as an agent between this national institution and the Seismological Regional Center for South America.

To carry out these duties, INPRES works through an internal organization; a General Director has responsibility over the following five departments:

- Seismology.
- Earthquake Engineering.
- Geotechnical and Structural.
- Surveying.
- Administration.

These activities are based on two main fields, seismology and earthquake engineering, and they are carried out according to a schedule that constitutes the national plan of seismic mitigation. It has funds totaling \$20 million for the first phase, the completion of which is expected towards the end of 1985.

National plan for seismic mitigation

The plan includes the following two main programs of seismology and earthquake engineering:

Program I: (Seismology). The study of seismicity and evaluation of seismic hazards in Argentina.

Program II: (Earthquake Engineering). The behavior of structures, building materials, and soil-foundation studies connected with seismic activity. These programs are concerned with obtaining, analyzing, and processing the data. The Institute is in charge of setting up and managing the national networks of seismological stations, accelerographs, and seismoscopes; the Central Laboratory of Materials Testing, Structures, and Soils; and the Computing Center for Processing Seismic Records.

National seismological network

This seismological network has been designed to operate 44 stations each with six, three, or one component elements and distributed throughout the national territory. At present, 11 stations are in operation and 4 others are being built. In addition, there are a number of seismological telemetric local networks planned for studying the siting of large dams, nuclear powerplants, and other critical facilities. Two of these networks are in operation at present: the San Juan local network is composed of eight remote stations and the Paraná Medio local network is composed of five remote stations. Other local networks such as the hydroelectric project of Yaciretá and Corpus at the Alto Paraná for the Argentine nuclear plan are in their early planning stages. In addition, INPRES has a portable seismological network composed of 15 portable seismographs which are mobilized in a

central unit equipped with a timing system, radio communication instruments, and accessories.

National network of accelerographs and seismoscopes

A network of accelerographs and seismoscopes has been planned that will cover all seismic regions in Argentina, taking into account the following factors:

- Seismicity and seismic hazards within the national territory.
- Importance of urban centers.
- Density of population.
- Characteristics of soil foundation.
- Siting of large engineering projects.

This network has 20 accelerographs and 112 seismoscopes installed in different places of the country. In addition, there are 22 accelerographs and 25 seismoscopes in the process of being installed. This national network, when completed in 1985, will consist of 215 accelerographs and 330 seismoscopes.

Central laboratory for earthquake resistant structures

One of the chief duties of INPRES is to carry out studies and technological research connected with building materials, soil foundation, building systems, and the behavior of materials subjected to seismic loads. The intention is to improve the building code and to improve methods for earthquake-resistant designs. To fulfill such a task, INPRES has a laboratory for testing structures, materials, and soils, which includes an 85-ton universal testing machine and a 200-ton press for testing concrete specimens, blocks, bricks, and so forth; the laboratory has also two consolidometers and auxiliary elements. The present instrumental capacity will be increased significantly

this year with the incorporation of an up-to-date system to generate and apply dynamic loads. Other essential equipment will be acquired during other phases of the plan; the equipment will include a universal machine for testing fatigue, electrically controlled consolidometer batteries, a chamber for triaxial testing, equipment for direct shear tests, and equipment for the drilling of soils, sampling, and field surveying.

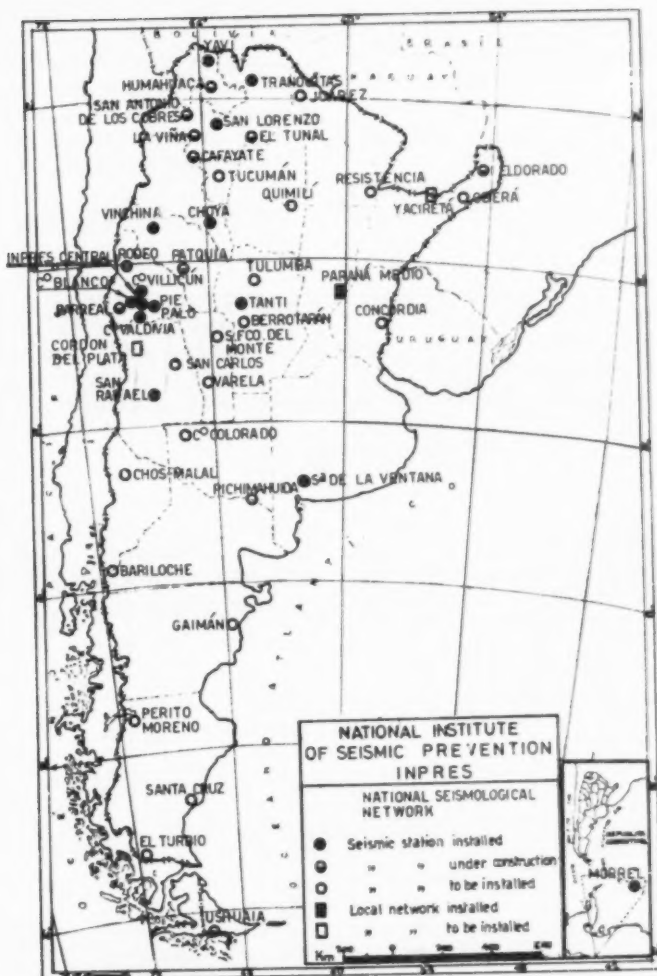
Analysis and processing of data

INPRES has a computer system whose operation analyzes and adequately processes the vast amount of data that will be provided by the national networks and the central laboratory.

Another project involves the development of a system which allows signals to be received directly from remote stations and to be handled as digital records by a computer system, and the system is expected to be completed by the end of 1982. Concurrently, software packages are being written that will allow one to automatically obtain a preliminary hypocenter location and the local magnitude determination of an event recorded on the digital seismic system of INPRES.

Current status of the program

For the two national networks, the task of operating and maintaining the equipment and calibrating the stations is proceeding on a routine basis. In addition, locations for new stations are being selected according to plan. Seismic zones have been determined statistically, and a seismotectonic map is being drawn up. A microzonation study of the urban areas in the province of San Juan is now in an advanced stage; the work is being carried out jointly by Argentine and U.S. con-



Distribution of stations in the Argentine National Seismological Network.

sultants. A similar plan is being developed for the Province of Mendoza.

Several special studies are being made for large engineering projects including:

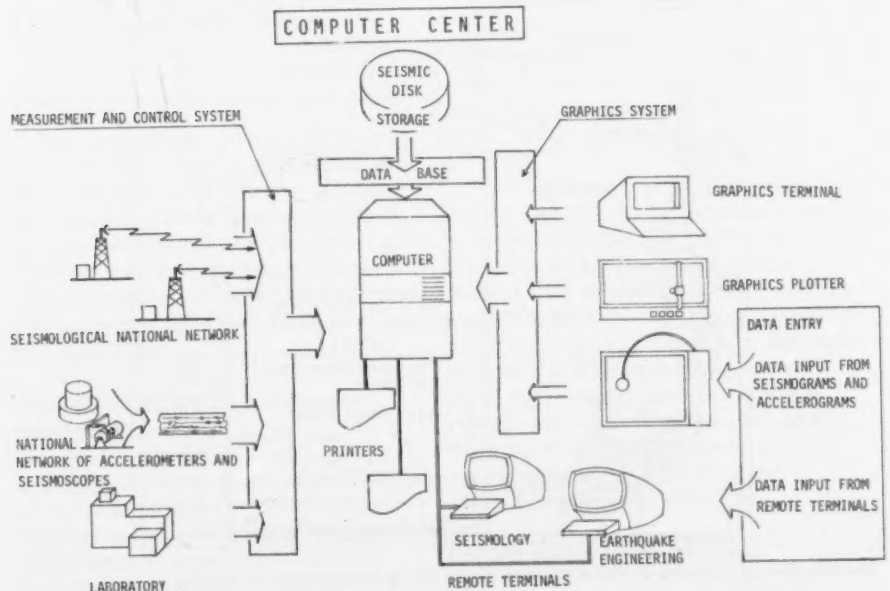
- **Paraná Medio project.** The first phase of this local telemetric seismic network has been partly completed with the installation of 5 of 11 seismic stations.
- **High basin of the Bermejo River project.** This local network is in the northwest of Argentina, and has at present 3 operating stations; 4 others are being built with an expected total of 12.
- **Alto Paraná project.** This local network for the Yaciretá and Corpus studies at the Alto Paraná is in its final stages.
- **Argentine nuclear plan.** INPRES has finished the final seismic report for the Embalse nuclear power-plant located in the Province of

Córdoba. In accordance with the Atomic Energy National Commission, the institute is considering new studies connected with the Argentine Nuclear Plan.

- **Cordón del Plata project.** Studies have begun for a network of three seismological studies to study the siting of the Cordón del Plata dam located in the Province of Mendoza.
- **Induced seismicity.** INPRES is studying the possible variations of seismic activity as a result of im-

pounding of reservoirs in regions of high, moderate, and low seismicity. Seismic activity is being monitored continuously in those areas where important dams are to be built.

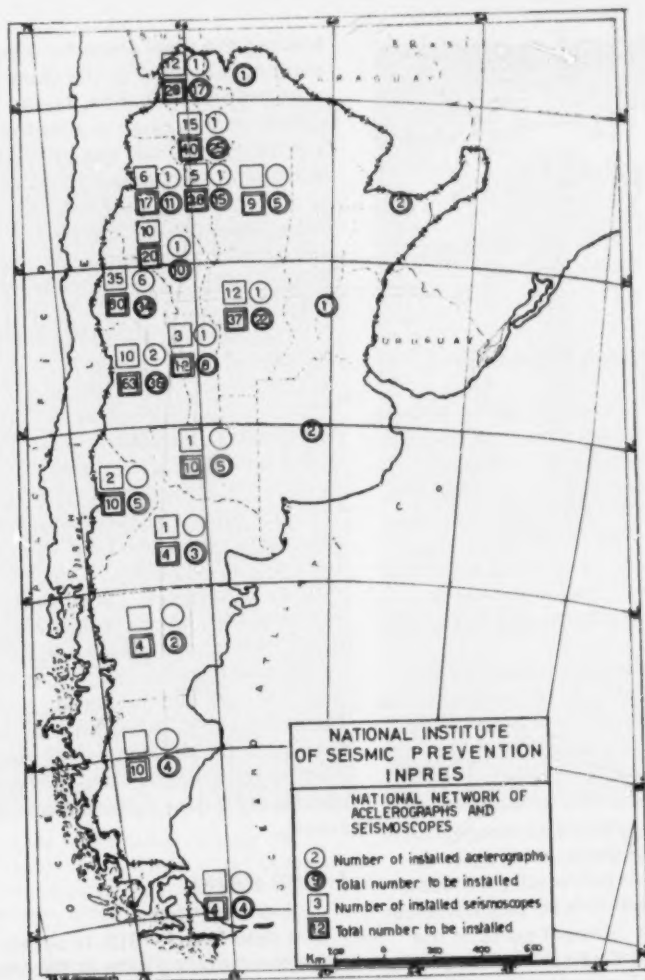
Beginning on July 1, 1981, the new regulations for earthquake resistant construction went into effect throughout the country. In accordance with the research center for the national building codes, studies of the performance of structures subjected to seismic loads are being carried out.



Flow chart for the computer center handling of data analysis and processing.

Portable seismological network.





Argentine National Network of Accelerographs and Seismoscopes.

International programs

The Andean Seismic Protection Project (PROSISAN) is a program to study Andean seismic protection, and it is organized and financed by the Organization of American States; the program is in its final stages.

SISRA is another program to study the seismicity of the Andean region and being managed by the Regional Seismological Center for South America (CERESIS). Its financial sup-

port is made by the U.S. Agency for International Development. The accomplishments planned for the first year include:

- Appointing national working groups with the cooperation of INPRES, universities, and private institutions.
- Preparing the methodology to be used.
- Holding the first coordination meeting in Lima, Perú.

Seismology in Bolivia—Close to the Stars

By Ramón Cabré, S.J.,
Observatorio San Calixto,
La Paz, Bolivia

Origins of Bolivian seismology

La Paz, the residence of the Bolivian Government (Sucre being the Bolivian capital) has had a seismic station since 1913 at an altitude of 3,658 m above sea level (12,001 ft). It has been described as "the single most important in the world" according to Richter and Gutenberg (1948) in their text *Seismicity of the Earth and Associated Phenomena*.

In 1881, the Bishop Calixto Clavijo donated a house built at the end of the 16th century to the Jesuits for a school. Ten years later, a meteorological station was installed, and this was the platform for the future seismological station. The Seismological Congress held at Manchester (England) drew up a resolution asking the Jesuit Order (which maintained seismological installations in different parts of the world) to install a seismological station in the heart of South America. Unaware of such a resolution, E. Tortosa, S.J., and ex-assistant of Rev. Sanchez-Navarro, S.J., at the Observatorio de Cartuja, Granada, Spain, arrived at La Paz and found to his surprise that his first responsibility was to install another station.

Immediately, both Tortosa and Lizaralde, his colleague, reevaluated the block occupied by the school and looked for the best location for the new station. The crypt, originally destined to be the Jesuits' cemetery,

seemed the ideal place for a seismic station, according to the observatory standards of the times. An old pendulum clock was soon adapted for timing; an alarm-clock was converted into the driving mechanism for a tin-plate drum supporting the band of smoked paper; straw levers provided mechanical amplification and a stylus holder and scrap iron, the inertial mass.

When the man considered to be the founder of the Observatorio San Calixto, the French Jesuit Pierre M. Descotes, S.J., arrived at La Paz at the end of 1911, good records were already being obtained. New heavier seismographs of the Mainka type were then designed and constructed at the observatory for a low cost with free oscillations of 12 and 14 seconds as well as a pendulum, called San Calixto, with free oscillations of 2.4 seconds. In those days, the streets were quiet, and science was not so exacting as it is today. The care and dedication of Father Descotes on the seismological station overcame any difficulties, so that the records obtained for large and regional earthquakes were considered to be superb.

Ancient station

The date May 1, 1913, is considered to be the founding date of the Observatorio San Calixto. Since then, the station (LPZ) has operated continuously until its turnover to a new station (LPB) outside the town that is part of the Worldwide Seismograph Station Network. The turnover was necessary because of the increase in downtown traffic. However, before the move, there was a substantial instrumental improvement of LPZ in 1930. The installation of a new set of electromagnetic seismographs constructed by Professor Wiilp, a student of Prince Galitzin at Tartu (Estonia), provided

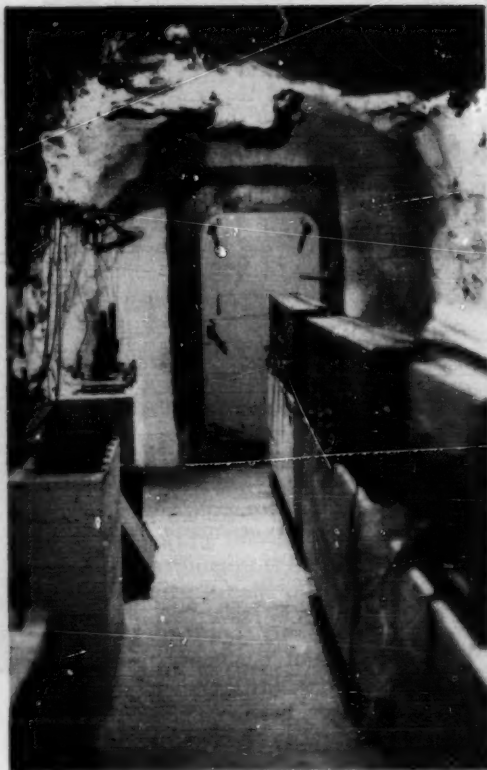


Entrance to the tunnel housing the station at the bottom of the exposed granite mass. Perennial snow tops the station. (Photograph by J. Nieva.)

seismograms which played a role in the finding that earthquakes could originate at much greater depths than expected, sometimes at 700 km.

Recent installations

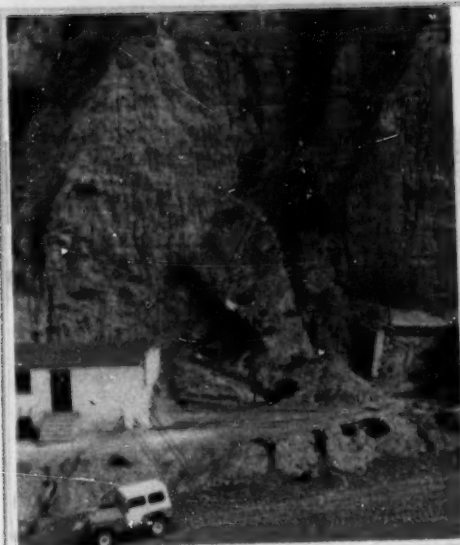
Station LPB was installed in 1962 at a lower altitude than LPZ, at only 3,292 m (10,800 ft) above sea level. The former U.S. Coast and Geodetic Survey provided the instrumentation, funding, and major maintenance for LPB. La Paz has continued to grow so that a telemetered station is now urgently



Photographic recording area of the Advanced Seismic Research Observatory (ASRO) station within the tunnel at 14,427 ft. (Photograph by J. Nieva.)

needed; in fact, its installation is being considered by the Geological Survey.

Although LPB was located at a lower altitude, another station was installed closer to the starts, 3,986 m (13,077 ft). It is PNS (Peñas), an LRSM-type station, installed on the Bolivian high plains by GEOTECH in 1963 and transferred to the Observatorio San Calixto in 1965; it operated there until 1975 and was sponsored by the U.S. Air Force. During part of this time, a station recording infrasounds was combined with the seismic station so that the atmospheric influence on long-



Seismic station LPB at 10,800 ft at La Paz, Bolivia. At right, seismometer vault; at left, small building containing recording, dark room, and guardhouse. (Photograph by J. Cerda.)



In the heart of the Andes below 1,000 ft of granite, pressurized tanks containing long-period seismometers are unaffected by atmospheric pressure oscillations. (Photograph by J. Nieva.)

period microseisms could be estimated. This contributed to the improvement of long-period records through the LPHG (long-period high-gain) and subsequent to the SRO (seismic research observatory) stations.

One of the LPHG stations was installed in a tunnel excavated through the granite of the Andes at 4,397 m (14,427 ft) in 1972 and later upgraded to the Advanced Seismic Research Observatory (ASRO) category; this required continuously recording on magnetic tape by three long-period components, as well as a short-period vertical component. In addition, a tripartite net of three Rocard short-period vertical component instruments operates in the same valley; through UHF radio telemetry, the net is recorded in the same tunnel.

In spite of financial difficulties, the Observatorio San Calixto, which is a

private institution, has continued its operation continuously assisted by the school, under whose umbrella it was born. Through the years, the observatory has been contributing data to the scientific community worldwide and has had the responsibility of seismological research on the Bolivian high plain, concentrating especially on seismicity and regional structure. This region in the Andean high mountains is geologically very complex and is one of the places where the Earth's crust is the thickest (210,800 ft).

Seismology in Brazil

*By Jesus Berrocal and Marcelo Assumpção,
Institute of Astronomy and Geophysics,
University of São Paulo,
São Paulo, Brazil*

Historical Review

Most of Brazil occupies the Precambrian shield area of South America; as such, it has a low level of seismic activity typical of intraplate regions. During the last four-and-a-half centuries, no single catastrophic seismic event has been reported in Brazil; a few events have produced intensities up to VII on the Modified Mercalli Intensity Scale (MM), causing more emotional effects and concern than any considered material damage.

Perhaps because of these aspects, seismology in Brazil had not received the necessary support in the past. Nevertheless, one of the first seismographic stations in South America, the Rio de Janeiro station (RDJ) has operated since 1906, and several compilations of felt earthquakes have been carried out.

In 1965, the Natal Seismographic Station (NAT) was installed as part of the Worldwide Seismographic System Network (WWSSN) VELA UNIFORM project and was initially operated by the Brazilian Navy. Routine analysis of the seismograms was not carried out either at this station or at Rio de Janeiro until recently, although seismic bulletins of station RDJ exist for the period 1906-40.

In 1966, a seismological expedition to South America was organized by the University of Edinburgh, Scotland, in cooperation with the Geophysical Institute of Peru and the Regional Seismological Centre for South

America (CERESIS); an experimental linear seismograph array was installed near Brasília. As a result of this expedition, it was decided to install a permanent linear array of seismographs, the South American Array System (SAAS) and a WWSSN station, both systems constituting the Seismological Station of Brasília which is currently under the Geosciences Department of the University of Brasília. Support for this station is given by the Institute of Geological Sciences of Great Britain, the U.S. Geological Survey, and the Brazilian National Research Council. The project also received support from CERESIS during the initial stages of the installation.

Routine analysis of the data from the experimental array-SAAS began in 1968 under the identification code BAE and continued in 1970 with data of the permanent SAAS under the code BDF. In 1972, a WWSSN station was installed in Brasília; since 1974, this station has used the BDF code, and the central point of SAAS has used the BAO code. Establishing the seismological station of Brasília gave the initial impulse to the development of seismology in Brazil.

During the last 10 years, significant advances have been made mainly due to the studies of seismicity and seismic risk related to the installation of hydroelectric dams and nuclear reactors in Brazil. In 1974, a seismological program was initiated at the Astronomical and Geophysical

Institute (IAG) of the University of São Paulo. In 1975, operation of station NAT was undertaken by the Federal University of Rio Grande do Norte (UFRN). In 1977, the National Observatory (ON) of Rio de Janeiro, that operates RDJ, also started its seismological program.

Most of the current Brazilian seismograph stations are operating with portable seismographs that monitor hydroelectric reservoirs; they have a peak response around 10 Hz that is suitable for recording local events, but not teleseismic events.

Seismological research in Brazil

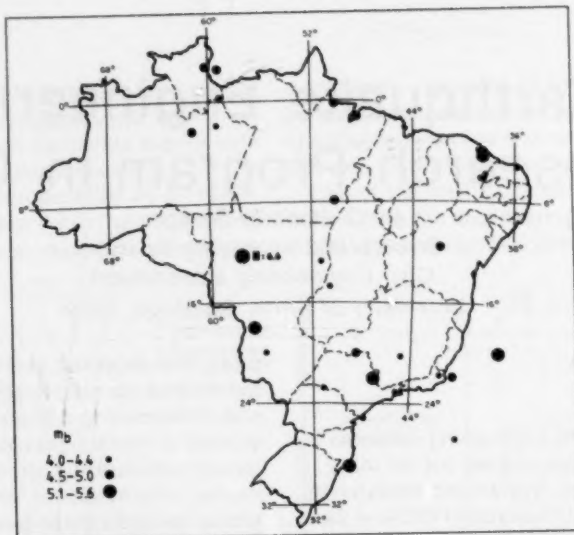
Seismological research in Brazil is currently carried out by two well-established groups at the Universities

of Brasília and São Paulo. Other groups, with personnel from UFRN and ON, are being formed in the postgraduate program of IAG. Other institutions, such as the Institute of Technological Research of São Paulo and the Federal Universities of Pará, Bahia, and Paraná, are also planning seismological research for the near future.

Additional support for seismological research projects in Brazil comes from the Brazilian National Research Council, the Foundation for Research Support of the State of São Paulo, the Brazilian National Financier of Research, the Brazilian Nuclear Energy National Commission (CNEN), and from the several hydroelectric companies that have installed local seismograph networks around their reservoirs.



Seismographic stations in Brazil. Solid circles are portable seismographs with filters set for local microearthquakes. Triangles are permanent and portable stations with filters more appropriate for teleseisms.



Epicenters of the main Brazilian events for the period 1900-80. Epicenters with uncertainties ≥ 100 km are not included.

Seismic readings are regularly sent to the National Earthquake Information Service of the U.S. Geological Survey and the International Seismological Centre (U.K.) from SAAS (BAO), Valinhos (VAO), Foz do Areia (FDA), Sobradinho (SOB), Natal (NAT), and Rio de Janeiro (RDJ).

The following are the main lines of research that are being carried out in Brazil:

- Brazilian seismicity and seismic zoning.
- Determination of intraplate lithospheric stresses in Brazil from focal mechanism solutions.
- Seismicity and seismotectonics of South America.
- Determination of upper mantle discontinuities under South America.
- Dam-induced seismicity.
- Seismic risk evaluation in areas of potential development of large engineering projects.

In the near future, studies of crustal and upper mantle structure are planned using surface-wave dispersion,

explosion seismology, and seismic-array methods. Microearthquake surveys in potentially seismic areas will also be undertaken.

Most of the projects mentioned above are connected with the Brazilian contribution to the new international program "Dynamics and evolution of the lithosphere: A framework for earth resources and the reduction of hazards."

Seismic activity in Brazil

Earthquakes have been known to occur in Brazil since 1560. Most of the earthquakes which have been recorded in Brazil were events felt mainly near the Atlantic coast, the region with the highest population density. Since the installation of the seismographic stations in Brazil over the past 15 years, several small seismic events have been located instrumentally. Early compilations of earth tremors in Brazil date from 1859. IAG, with support from CNEN, is currently compiling all available information on historical and instrumentally located seismic events.

Earthquake Engineering Research Program in Chile

By G. Rodolfo Saragoni,
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Introduction

Earthquake engineering research in Chile has been carried out for more than 30 years. Systematic research is done at the University of Chile in Santiago. Other universities such as the Catholic University, University of Concepción, and the Federico Santa María Technical University have begun to teach and conduct research in earthquake engineering in recent years.

The fields of research at the University of Chile include the following:

- Theoretical and empirical characterization of strong ground motion.
- Installation of strong-motion accelerographs.
- Capacity of strong ground motion to produce structural damage.
- Seismic risk.
- Seismic behavior of reinforced masonry houses and buildings.
- Seismic design of high-rise buildings.
- Soil dynamics with emphasis on soil liquefaction and soil stability.

Capacity of strong ground motions to cause structural damage

The Scientific Development Office of the University of Chile has granted a 3-year research project on "Earthquake Destructiveness." In this project, strong ground-motion parameters are identified that control ductility requirements for simple nonlinear struc-

tures. The expected ductility requirements for simple elastoplastic and stiffness-degrading structures are studied in terms of expected maximum ground acceleration, duration of strong motion, and frequency content. These topics are considered part of the earthquake parameters. The natural period and damping of the structures are considered the structural parameters.

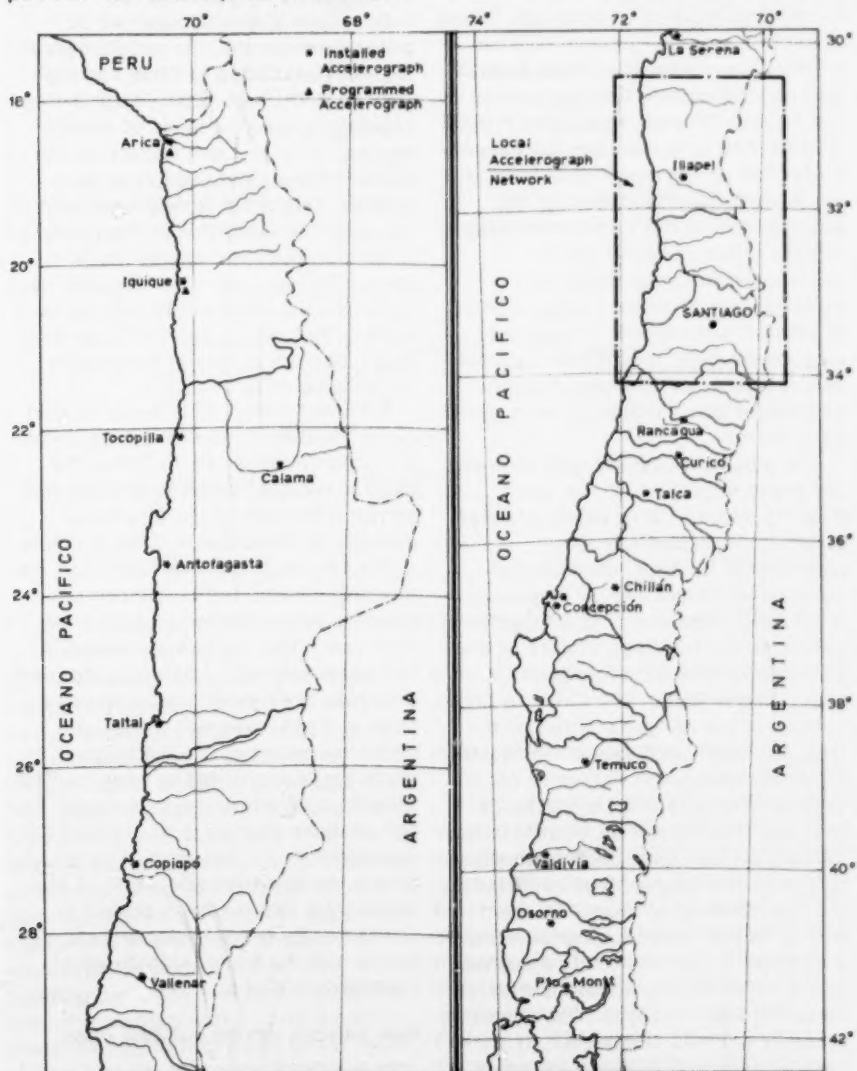
The results obtained so far are very significant when accelerograms recorded in strike-slip areas are compared against those recorded in subductive zones. Subductive earthquake accelerograms, for instance in Chile and Peru, usually have larger values of the "intensity-of-zero crossings" than those accelerograms obtained from strike-slip events in California. Henceforth, it is possible to record accelerograms in the former zones with very large ground acceleration without producing significant structural damage. This solution explains, in part, the large differences in structural damage observed during strong earthquakes in different tectonic settings. Also, this is of particular interest when the "structural response" shown in accelerograms generated by subduction seismic events in Alaska, Chile, and Japan is compared with the "structural response" produced by strike-slip seismic events in California and in some regions of Central America. The application of some of these results has a direct impact on the seismic design code in South America; on a

preliminary observation, it implies that subductive earthquakes are less destructive than California events with similar Richter magnitudes.

Strong-motion duration as an earthquake parameter from the engineering point of view can duplicate ductility re-

quirements. However, its influence can be considered secondary to the effects of expected maximum ground acceleration and "intensity-of-zero-crossings."

One of the main conclusions obtained from the engineering ductility study is that a seismic design code for



The Chilean national accelerograph network in December 1980.

Chile, and likewise for other South and Central American countries, should not be a straightforward duplication of the California building code.

Andean Seismic Protection Project

The Organization of American States (OAS) has supported since 1978 the multinational project entitled Andean Seismic Protection. The main scope of the Andean Seismic Protection Project (PROSISAN) is to increase the seismic protection of manmade structures in the Andean countries through the development of better seismic design criteria; these consider the socioeconomic importance of buildings, the regional characteristics of seismic activity, the influence of local foundation, the seismic behavior of structures, and the regional procedures of construction in each participant country.

The project was developed between Chile and Argentina; at the last meeting (March 1981), Venezuela was incorporated into the project represented by the Foundation for Venezuelan Seismological Research (FUNVISIS). Representing Chilean institutions are the Departments of Civil Engineering and Geophysics of the University of Chile.

Most of the budget granted by the OAS has been used to expand the national accelerograph network from 40 to 60 accelerographs. Ten of the 20 new instruments will be located in the Valparaíso-La Ligua-Santiago region this year. The new array is expected, in the next decade, to record an event with a Richter magnitude greater than 8 offshore Valparaíso as its epicenter and another of magnitude 7.5 with its epicenter near La Ligua. The 10 new systems with the existing 11 accelerographs will increase the probability of obtaining strong-motion records of earthquake engineering and

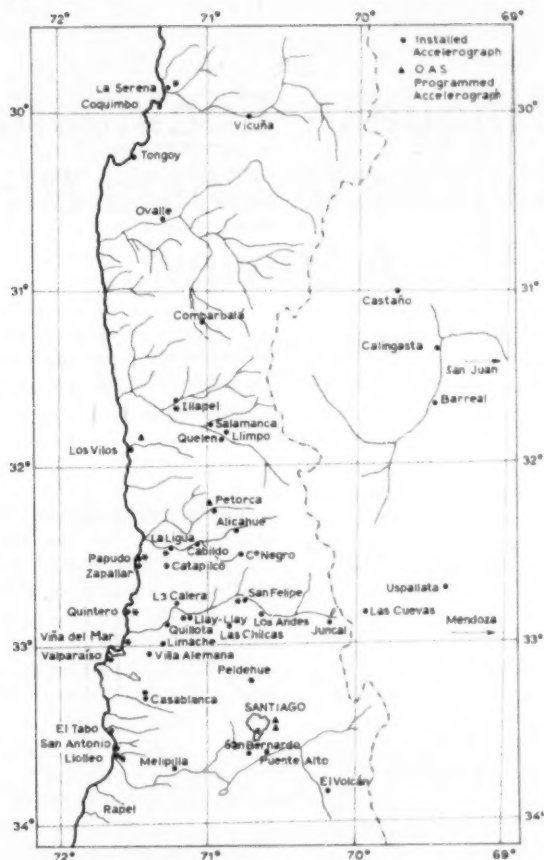
near field interest in the meizoseismal region and (or) in populated areas. The distribution of the instruments in the network enables one to study azimuthal effects also.

The University of Chile network is enhanced by 10 additional accelerograph stations deployed by private companies. The accelerograph station installation in Chile has high priority in the earthquake-engineering research project because of the difference in destructive capability between Chilean and California earthquakes. This point is very important in the final consideration of the building-code changes that may be made in Chile. The national accelerograph network and the local accelerograph network in the Valparaíso-La Ligua-Santiago area are shown in the accompanying figures.

A second topic under study as part of PROSISAN is the seismic behavior of reinforced masonry in Chile. The earthquake destructiveness study has shown that most of the structural damage documented in Chile is found in low-to-middle highrise buildings, particularly houses and buildings constructed with a limited budget. In recent years, this type of construction has been built with reinforced masonry and does not have a special seismic code. A 4-year research project is underway with partial OAS support to study the theoretical and experimental seismic behavior of masonry walls. The aim of these studies is to produce the requirements for this type of construction in the seismic code. Most of the support for this research project is sponsored by the Ministry of Civil Works and the National Institute of Standards of Chile.

New seismic design building code

During the last 6 years, much research has been devoted to review and to complete the 1972 Chilean Code



The local accelerograph network in the Valparaíso—La Ligua—Santiago region in December 1980.

on the Seismic Design of Buildings. Research related to the new code includes seismicity and seismic risk in Chile, microzonation of the main Chilean cities, ductility and seismic behavior of material and construction procedures, and static and dynamic seismic-design procedures for highrise structures. Most of the research has been accomplished with the support of PROSISAN and the Earthquake Destructiveness projects. The new building code will have the microzonation of the entire nation, and it will include microzonation maps of the main cities, design spectra, and explicit ductility requirements. A new proposed seismic-risk technique is being con-

sidered to evaluate the destructiveness potential of Chilean earthquakes.

International program of research

The University of Chile has had a masters degree program in earthquake engineering since 1972; under this program, some engineers from South American institutions concerned with seismic prevention have received their training. The University of Chile has an official international program in earthquake research with the University Federal of Rio Grande do Sul, Brazil; Technische Universität of Munich, Germany; and Hokkaido University, Sapporo, Japan.

Earthquake Engineering Activities in Costa Rica: A Review

*By Jorge A. Gutiérrez,
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Introduction

Costa Rica is located in the circum-pacific belt at the boundary between the Cocos and Caribbean Plates, with the Nazca Plate and the Panama fracture zone at its southern border. The country has a long record of historical seismicity that goes back to the earliest Spanish chronicles. In 1841, after an earthquake destroyed more than 4,000 dwellings, President Braulio Carrillo implemented the first seismic code. Early seismological observations started in 1888 at the Instituto Físico Geográfico, but unfortunately this important activity was curtailed after two decades.

A significant investment in public works during the 1950's and 1960's was the main contributor to a renewed interest in earthquake engineering among professional engineers and seismologists. This interest has flourished during the last decade, and this paper will briefly review the most significant activities.

The 1974 seismic code

In 1973, the Colegio Federado de Ingenieros y Arquitectos de Costa Rica, the national professional engineering and architectural society, established a

committee in charge of drafting a seismic code. The decision was a logical consequence of the concern created by the Managua earthquake of 1972 and the Tilarán, Costa Rica, earthquake of 1973. In October 1973, the first draft was submitted for discussion and it was approved by the Colegio in January 1974.

To ease acceptance of the seismic code, the committee was declared a permanent national committee, and the membership was increased by four. Several seminars were organized, University courses dealing with the basic principles of earthquake engineering and structural dynamics were established at an undergraduate level, and code commentaries were published. As a consequence, the code became an important means of introducing to the engineering profession more modern and refined methods for analysis and design and better inspection practices.

The code has 2 parts and 21 chapters contained in 91 pages. Rather than a simple regulatory document, the code tries to explain the underlying philosophy of analysis and design. This viewpoint was considered necessary for a more creative interpretation of the code and for less of a dogmatic use.

One of the most important activities of the permanent committee was in working with the national Parliament to give a legal character to the code. As a result, a law was approved in 1977 that states that all public works must comply with minimum earthquake-engineering regulations; these regulations must be issued by Executive Decree with the mandatory advice of the code committee. With the newly adopted procedure, it became relatively straightforward to introduce partial or total revisions to the legal code without parliamentary approval.

Research on Costa Rican seismicity

In 1973 when the code was drafted, there was insufficient information for reliable seismic zonation; therefore, the country was assumed to be seismically uniform. The need for seismic zonation became evident, and research activities in this direction were initiated.

The most comprehensive study, to date, of seismic risk in Costa Rica is by Mortgat and others (1977). Nevertheless, the data available at the time of Mortgat's study can be questioned for the following reasons:

- Data on focal depth were not always complete; the depth was assigned on the basis of data for nearby events.
- Some magnitudes were body-wave magnitudes and others had letters defining magnitude intervals; in all these cases, a Richter magnitude was recomputed.
- All the information is based on teleseismic data with large uncertainties in epicentral locations and without regard for some very important earthquakes in the past which were near populated areas in Costa Rica.
- There is a very large concentration of events in the last decades of

the time interval studied, especially for moderate and small magnitude earthquakes.

- There is no available information on strong ground-motion attenuation in Costa Rica.

To overcome these deficiencies, a research program on Costa Rican seismicity has been initiated. A National Seismological Network has been established with the participation of the Instituto Costarricense de Electricidad, the Geography Department of the National University, and the Geology Department of the University of Costa Rica. In this new program, faults are being identified and mapped, and their classification is under study. Epicenter errors have been minimized, and as a consequence, a more refined definition of the seismic sources is becoming available. Historical events have been reevaluated on the basis of new information extracted from historical chronicles, and their epicentral locations have been changed. Concurrently, a small strong-motion network has been established in the city of San José. Although this network is insufficient and should be instrumentally increased to cover the most seismic and populated regions of the country, it represents a potential source of strong-motion data which will enhance the data base for attenuation studies. With the above information, it is expected that in the next few years a new and more reliable estimate of seismic hazards will become a reality.

In 1979, the University of Costa Rica created the Center for Geophysical Investigations (Centro de Investigaciones Geofísicas: CIGEFI). The Center is in charge of all research activities in the field of geophysics, with priority on seismology. Its main areas of interest are natural disaster prevention, structure and dynamics of geophysical

systems, and natural and nonconventional energy resources. For a young research center, CIGEFI, the present number of research projects and publications being undertaken shows an above-normal active group. With adequate financial support, it has excellent possibilities of becoming a major research center in the Central American region.

Research in earthquake engineering

Most of the research activities in earthquake engineering are presently being conducted at the Civil Engineering Department of the University of Costa Rica. The research program approved for 1981-85 includes the following:

- *Study of different seismic inputs on structures.* This topic is closely related to the seismotectonic studies of CIGEFI. In addition, it includes research on the effect of local site conditions on the earthquake signal and on the random generation of artificial accelerographs.
- *Computer software simulation for dynamic analysis.* Most of the well-known computer programs have been implemented at the university computer center so analytical work may be performed on complex structures; new programs have and are being developed.
- *System parameter identification of existing buildings.* This is a very important subject, if adequate analytical models are required. However, instrumentation is not available at this time; the type of equipment needed in this program is useful for many other engineering applications.
- *Analytical and experimental studies of materials and construction*

methods used in buildings and dwellings.

- *Studies related to seismic design regulations.* This is an ongoing research effort which is closely related to the activities of the Costa Rica Code committee; many of the regulations included in the new code have been the result of university research.
- *Socioeconomic impact of earthquakes.* This is a very important area in terms of the benefits that the country may derive from a prior rational understanding of the earthquake factor and its effect on the public welfare.

The earthquake-engineering program is an ambitious one with medium-term goals. At present, an emphasis is being made of the considerable benefits that would be derived from such an applied research program in return for support by the Costa Rican government.

The 1981 seismic code

Feedback from the professional community over 7 years, information about Costa Rican seismicity, and the national and international research in earthquake engineering are being combined in a complete review of the 1974 seismic code. It is likely that this effort will be completed shortly. The main feature of the new code, apart from changes in regulations, is its totally different organization. It is divided into sections; the first one includes general information and regulations applicable to all types of structures—design philosophy, regional seismicity, load combinations, and so forth. The second section applies to buildings and includes regulations of their analysis, design, and construction. The third section refers to one- and two-story

dwellings and includes simplified procedures for this type of construction which are not necessarily designed by structural engineers. Additional sections will subsequently involve bridges and possibly harbor structures, lifeline facilities, storage tanks, and other special structures. The code's organization allows for changes in single chapters or entire sections, without altering the remaining parts.

Earthquake-engineering activities in Costa Rica are an incipient but a prom-

ising activity. Most of the research in seismotectonics and earthquake engineering has taken place during the last 5 years. There is an urgent need for financial support from nonuniversity sources, in order to increase the amount and the scope of the research. Even though no major earthquakes have occurred in the region in recent years, it is quite obvious that all these seismological and engineering activities have considerably reduced the earthquake hazard in Costa Rica.

Seismology in Mexico

*By Cinna Lomnitz,
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Systems Analysis,
National University of Mexico, Mexico City*

Mexico is situated at the intersection of four major crustal Plates: the Americas Plate, the Pacific Plate, the Caribbean Plate, and the Cocos Plate. The interaction of these four plates is very complex. The pattern of earthquake risk is, therefore, among the most complicated in the world. The average release of seismic energy each year is 55×10^{21} ergs—more than twice the figure for California.

One of the major objectives of seismological investigations in Mexico is to determine regional seismicity parameters as a means of improving the estimation of earthquake risk throughout the country. This is a task of great economic importance because of the seismic vulnerability of major cities and factories. The rapid industrialization of the countryside and the planned construction of large dams, powerplants, and industrial centers throughout the country emphasize the need for an accurate and reliable measure of earthquake hazard in relatively remote regions, where few seismic data had formerly been available. A thorough knowledge of the earthquake hazard for preventing damage and loss of life is, therefore, essential.

Several of the following research groups in seismology are active in Mexico: at the Institute of Applied Mathematics and Systems Analysis; at the Institute of Geophysics; at the Institute of Engineering; and at the Ensenada, Baja California, Research

Center (CICESE). The first three facilities belong to the National University of Mexico (UNAM), in Mexico City.

Red Sismica Mexicana de Apertura Continental (Mexican Continental Aperture Seismic Array, RESMAC) is the new digital telemetry network which is scheduled to cover most of Mexico via the nationwide microwave communication network. RESMAC is located at the Institute of Applied Mathematics and Systems Analysis in Mexico City. The fundamental difference between a network and a seismic array is that networks are sets of stations under a single administration, but otherwise operate as individual units; an array, such as RESMAC, is a system of remote sensors controlled from a central processor unit and operated as a single device. Seismic arrays have been used in petroleum prospecting for decades, but their application to earthquake seismology began only about 10 years ago.

At present, 11 stations are connected to RESMAC, covering central Mexico from coast to coast. Any repeater tower may be used as a terminal for connecting a remote seismic sensor. Most repeater stations are located on mountaintops in hard rock, usually ideal sites for seismic recording. The system issues a biweekly bulletin containing locations and magnitudes of local and regional events and selected teleseisms. Because of the automated procedures used, the bulletin is updated every day

and is sent out within hours of the closing date. Accurate central timing is used.

All the equipment for RESMAC was designed and built at the Institute. Basically, four stages of cascade amplification are used at the input, thus obtaining four dynamic ranges. Each digital sample contains a range index; there are 36 samples/sec for short-period sensors, and 4 samples/sec for long-period instruments. Because all information is transmitted in digital form, there is no distortion in the microwave transmission. Our experience with this system has been excellent, and reliability has been very high.

At the RESMAC data center at the National University of Mexico, the digital information is serially fed into a DEC 11/40 computer using software designed at the Institute. The system detects and stores all seismic events which trigger at three or more of the stations in the array. Currently, all events in central Mexico of magnitude greater than 2.5, offshore events greater than about 3.5, and distant regional events of magnitude 4.0 and greater are detectable.

Data analysis is performed on a video display screen by manually positioning crosshairs to pick out the arrival times or intervals for magnitude calculations. New features are continually being added to this analysis program. At present, the package includes the following:

- Location programs for local earthquakes and for teleseisms.
- A Wood-Anderson simulator for magnitude determinations.
- A cross-correlation program for identifying first arrivals in noisy records.
- A fast Fourier transform package for computing spectra.
- Various filtering routines, both on-line and off-line.

- Interpolation routines for handling missing data or spikes.
- Many other items.

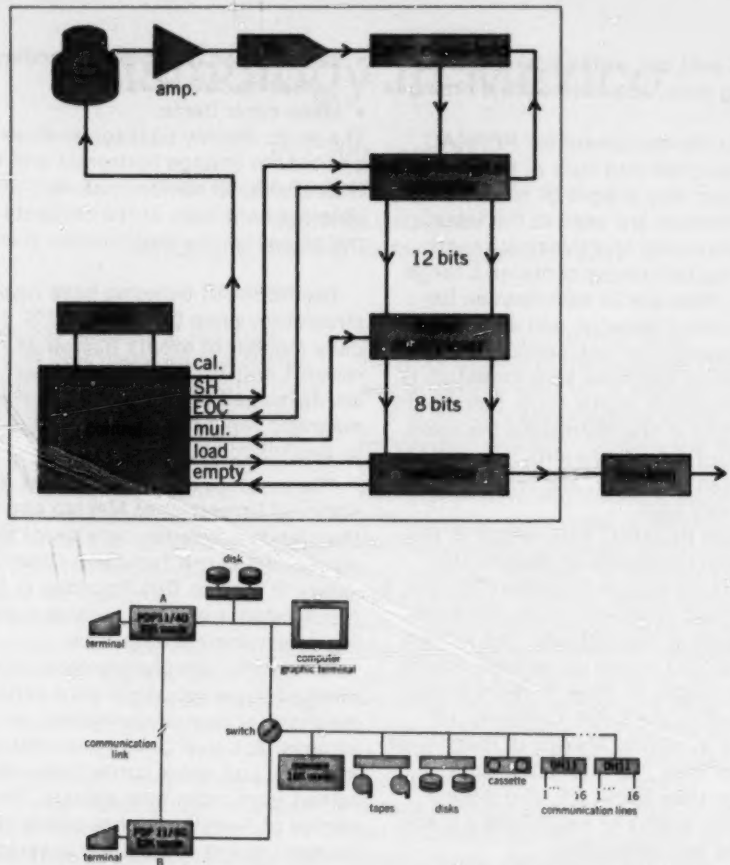
The basic display package enables the operator to change horizontal and vertical scales, to switch channels, and to obtain a hard copy of the contents of the screen on the electrostatic printer.

The RESMAC bulletins have been in circulation since December 1979. The daily number of events fluctuates between 1 and 10. All locatable events are cataloged and permanently filed on magnetic tape; the data are available to seismologists on request.

The Institute of Geophysics at the National University of Mexico operates the standard seismic network of Mexico, including the Tacubaya Observatory in Mexico City (founded in 1906). It publishes a seismic bulletin containing seismological data. The seismograms are photographic or smoked-paper records from a variety of mechanical or electromagnetic instruments. Local clocks are used at all stations, and clock corrections are obtained from radio time signals. The Institute of Geophysics has plans to modernize and expand the coverage of the service. This organization is in charge of officially disseminating seismic information to the public.

The Institute of Engineering at the National University of Mexico operates a network of frequency modulated (FM) telemetry systems around Mexico City; the systems include four short-period seismological stations and a number of strong-motion stations in the urban area. The Institute is also responsible for the operation of local accelerographs at many locations in Mexico, especially in industrial and urban areas.

The Baja California seismic network is operated by the Ensenada Research Center (CICESE), an independent center for graduate studies located on



A single-component seismograph remote system of RESMAC and its central data processing system is shown schematically with a two-computer (A and B) tandem arrangement.

the Pacific coast south of Tijuana. There are four digital telemetric seismological stations in the Colorado River delta, and more stations are being installed elsewhere in northern Baja California. Eventually, there are plans to instrument the entire peninsula and selected locations on the coast of Sonora.

Seismological research in Mexico includes contributions by members of all four active institutions mentioned previously and by foreign groups. Mexico has maintained distinctly critical

scientific attitudes towards fads and fashions in earthquake-prediction research.

Major research results from RESMAC include the discovery of plate waves from aftershocks of the intermediate-depth earthquake of October 24, 1980, which was destructive in the region of Huajuápan, Oaxaca. These new phases are believed to have propagated in the subducted Cocos Plate as a waveguide; they provide the first positive evidence of the presence and position of this subducted Plate in Mexico.

Engineering Aspects of Seismological Studies in Perú

*By Leonidas Ocola,
Geophysical Institute of Perú,
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Large and small earthquakes occur frequently in Perú. Official institutions in charge of the study of seismological and geophysical aspects of such large natural events have a responsibility to provide engineers, planners, and government officials with the basic data to implement safety measures to minimize the destructive impact of great earthquakes. The Geophysical Institute of Perú (IGP) is one such institution.

The interest of the scientific community in earthquake studies has been high in Perú for a long period of time. In contrast, the engineering and social aspects of earthquakes have been studied only for the past decade.

In retrospect, the Peruvian national long-range earthquake-study program began after the catastrophic earthquake of May 31, 1970. This earthquake triggered a large snow avalanche from Huascarán mountain, killing over 60,000 people, and covering with mud small cities and tens of villages in the Andean valley of Callejón de Huaylas, Huaráz. Since then, great efforts have been made to learn about the natural seismic environment and its engineering and social aspects. The Organization of American States (OAS) has

been one of the most important agencies in the development of the program.

Seismological net

Perú had three permanent seismological stations until 1970, at Huancayo Observatory, Ñaña, and Arequipa. The last two stations are part of the Worldwide Standardized Seismograph Network (WWSSN). In the decade of the 1960's, there were seven Carnegie Institution of Washington-Department of Terrestrial Magnetism (CIW-DTM) semiportable seismic stations in southern Perú. Five of these stations were operated by the Arequipa National University in cooperation with CIW-DTM; and two of them by the IGP. These stations did not operate continuously, and only three of these stations are presently in operation.

The national seismological net in 1981 had in operation 27 semiportable seismographic stations, 2 WWSSN, and 3 broadband permanent stations (CIW-DTM). The distribution of stations are shown in the figure. In the early stages of the program, the economic and technical support of the OAS was of great importance under Programa Regional de Desarrollo Científico y Tecnológico, which started immediately after the 1970 great Huaráz catastrophe. During subsequent years, the program has benefited from the financial assistance of Holland through the United Nations in 1975; the technical advice and equipment loans from CIW-DTM; the technical assistance and equipment from the seismology group of the University of Wisconsin, Geophysical and Polar Research Center; and from the scientific advice of U.S. Geological Survey experts from the Denver seismology

Seismic and strong motion nets:

A. Strong motion net:

1. Special projects' SMA-1.
2. OAS' SMA-1 station.
3. U.S. Geological Survey Montana station.

B. Seismic net:

4. Special projects short-period seismic stations.
5. OAS' short-period (Sprengnether MEQ-type).
6. UN-IGP short-period (Sprengnether MEQ-type).
7. DTM short-period stations.
8. NOAA-IGP short-period tsunami monitoring system.
9. WWSSN.
10. CIW-DTM broad-band station.
11. IGP short-period station.
12. Special project, short-period, remote-seismic RF-telemetric station.
13. UN-IGP short-period, remote-seismic RF-telemetric station. Stations at La Ayanquera, San Gregorio, Ongoro, and Arequipa are operated by Universidad Nacional de San Agustín de Arequipa. Stations at Cuzco and Trujillo are operated with the cooperation of CIW-DTM.
14. Remote-seismic RF-telemetric station.



group. All of these organizations have contributed to the instrumentation of the present seismological net and towards the development of our overall geophysical program in Peru.

The purpose of the semiportable seismic net is to acquire high-quality data from which one can better understand earthquake mechanisms. The results obtained will be used to recommend, for instance, the implementation of preventive measures to minimize damage to manmade works, and to reduce loss of life caused by destructive earthquakes.

Strong-motion network

It is of vital importance to have knowledge of the dynamic characteristics of ground shaking caused by earthquakes. To this end, the IGP has made a great effort to develop a basic network of analog strong-motion stations.

Until 1970, there was only one U.S. Geological Survey Montana-type accelerometer installed at the IGP office in Lima. There are 16 strong-motion stations at present; 5 are placed on sites where great dams or structures

are being planned, 5 are instrumenting a gravity dam in northwest Perú, and the rest are distributed throughout the main cities.

It is important to emphasize the support given by the Programa Regional de Desarrollo Científico y Tecnológico of the OAS in the acquisition of the first SMA-1 strong-motion units. These stations enabled the personnel of IGP to learn the operation, maintenance, and data processing of strong-motion instrumentation.

The number of strong-motion stations will be increased in the near future by using digital-data acquisition systems. Strong-motion information will provide not only the basic data for earthquake-resistant structural design and the implementation of the national building code, but this information will make possible the study of near field characteristics of earthquakes in order to understand focal processes and attenuation of strong-ground motion in a subductive region of the world.

Regional seismic hazard assessment program

This program was developed under the auspices of the OAS; in 1973, the Andean Seismicity Multinational Project (OAS IRI-21) was initiated with the participation of Bolivia, Colombia, Ecuador, and Perú. One of the main goals of this SISIS program was to obtain basic earthquake-engineering information to prepare and improve existing building codes. At the beginning of the project, the main effort was aimed at implementing data banks and developing methodology for regional seismic-hazard assessment.

An important and timely series of lectures and workshops was programmed under the OAS-USGS-IGP Lima Seismic Risk Project, given during 3 weeks in September 1974. Participants included S. T. Algermissen, A.

F. Espinosa, E. Dobrovolsky, R. B. Mathiessen, and H. Olsen, all of whom are authorities on local and regional seismic-hazard assessment. These lectures and workshops laid the cornerstone for the development of the present seismic-hazard assessment and seismic-microzoning programs being carried out at the IGP and at several university engineering departments, including the Catholic University and the National Engineering University of Perú.

Three data banks were originally planned in the SISIS program—historical ground shaking, instrumental hypocenters, and geological data. Because of a manpower shortage, only the first two data banks have been implemented. However, sufficient geological material was gathered for a reliable data base on the regional tectonics of each country.

The historical data bank was obtained by means of a careful survey of historical documents or summaries of such documents. The main source of information on Perú is Silgado's 1973 and 1978 publications. The interpretation of maximum severity of ground shaking reported in Silgado's publications and other documents is presented in the intensity map in terms of the MSK (Soviet) intensity scale. The intensity values of this map do not necessarily represent the maximum intensity of ground shaking associated with a particular seismic event, nor do epicenters of the historical earthquakes coincide with the location of the circles shown on the map. Historical records are inevitably incomplete, and, in early times, the country was sparsely populated. In spite of these deficiencies, the map shows severe ground shaking along the coastal area where destructive events seem to have been much more frequent in the last 500 years than those occurring along the sub-Andean

seismogenic region. Events along the sub-Andean region cause much more severe ground shaking than those along the coastal region. Nevertheless, the intensity of shaking attenuates much more rapidly with distance, because most of the sub-Andean activity is very shallow.

The instrumental hypocentral data together with geologic and tectonic information have been integrated to outline the geometry of the main seismogenic zones. In addition, statistical properties of earthquake occurrences, assuming a Poisson probability distribution, have been evaluated. For each zone, laws for the generalized severity of ground shaking attenuation have been determined for the upper boundary of maximum intensity distribution, as a function of hypocenter distance and magnitude of the seismic event. Thus, the levels of seismic hazard computed using these laws are highly conservative.

Four main seismogenic zones have been determined in Perú: the Arica-Nazca and Nazca-Paita zones both along the western border of the South American Continent (interplate seismogenic zones); the Ayacucho-Moyobamba zone continuing to Riobamba (Ecuador); the northern sub-Andean seismogenic zone and the Abancay-Puno zone continuing through Cochabamba (Bolivia) towards the southeast (the southern sub-Andean seismogenic zone). These last two zones are the sub-Andean intraplate seismogenic zones. Besides the four seismogenic zones identified in Peruvian territory, the seismic-hazard level is strongly influenced by the intraplate Guayaquil-Quito seismogenic zone in northern Perú (continuing towards Bogotá, Colombia, and then into Venezuela) and the Arica-Taital (Chile) zone in the south.

Through the SISAN project, the geometry of each seismogenic zone, a

statistical description of the seismic activity, and the characteristic intensity of ground shaking and attenuation laws have been determined for each seismogenic zone. The computation of probabilistic seismic-hazard levels for several exposure times was carried out using a modified Cornell-McGuire algorithm. A preliminary seismic-hazard map for Peru is shown.

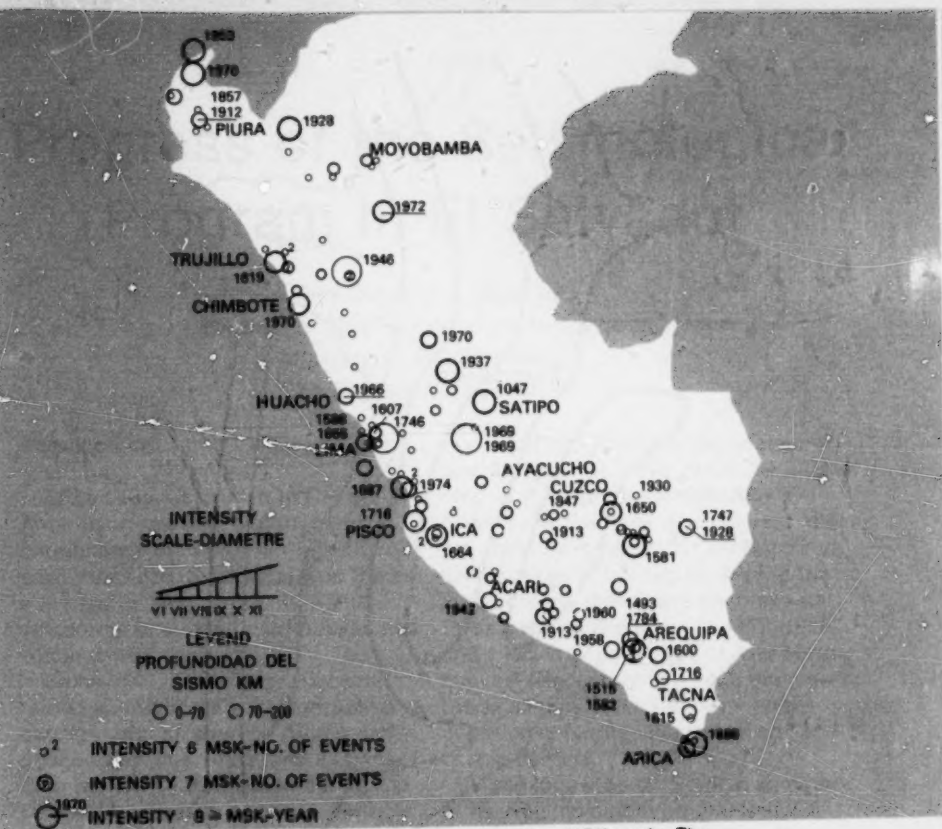
One of the new findings of this study is the high level of seismic hazard associated with the northern sub-Andean intraplate seismogenic zone. This was not recognized before, as can be seen in the official 1977 seismic-zoning map of Perú. The study of this seismogenic zone is important, because the future socioeconomic development of Perú will be along or close to this area of high seismic hazard.

Seismic microzonation and site studies

The seismic-microzoning program in Perú was initiated under the auspices of the OAS project—Proyecto Multinacional de Ciencias de la Tierra. In the early stages of this program, the main effort was concentrated on developing and implementing an appropriate methodology to design, build, and assemble systems to acquire the data and train the personnel.

The methodology takes into account the regional seismic hazard, the local geologic and soil conditions, and the spectral content of the strong ground shaking caused by events of large magnitude. This methodology was applied to microzone the area of the future industrial complex of Bayóvar, Piura, in northwest Perú.

The IGP microzoning program also used the distribution of severity of shaking caused by a moderate earthquake to microzone the city of Arequipa in southern Perú. An earthquake ($M_s = 6.9$) occurred about 60 miles from

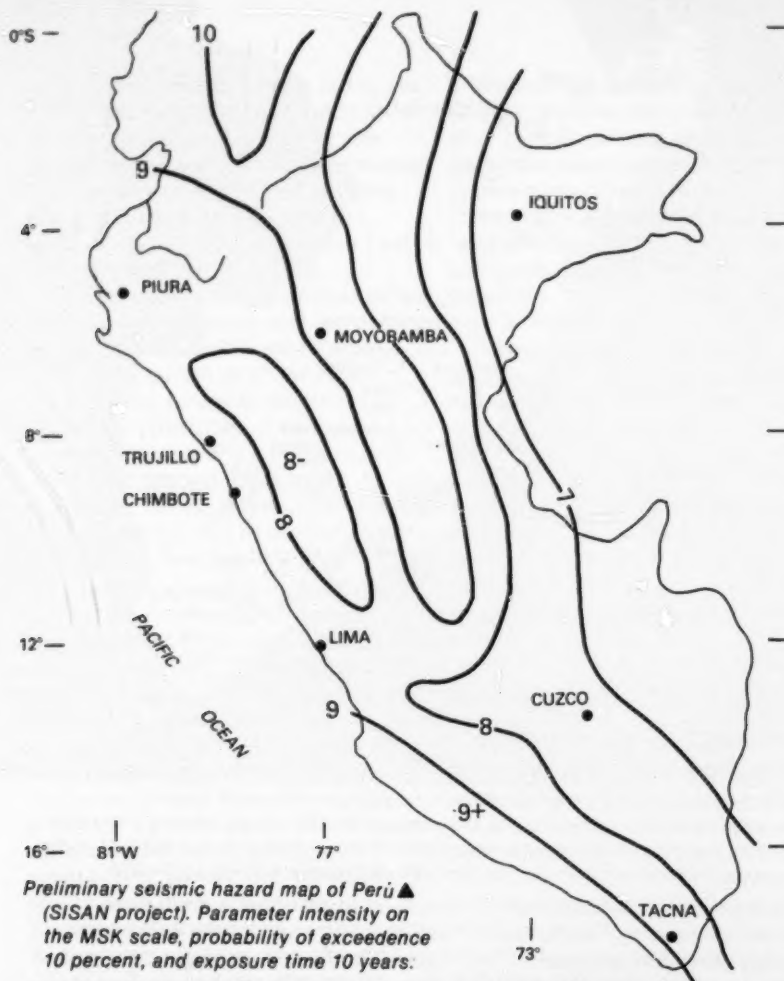


Maximum-intensity map for Perú of historical earthquakes, MSK scale. The diameter of each circle is a measure of intensity on the MSK scale. Most of the earthquakes along the coast had probable epicenters offshore. This map is a product of the SISEAN project. Intensities taken for the Peruvian earthquake catalog 1471-1974.

the city and shook the metropolitan area with an intensity 6-7 MSK. The methodology considers an areal systematic sampling, a careful observation of the quality of building materials and workmanship, and a detailed survey of damage on structural elements and masonry. A comprehensive interpretation of the data allowed an estimate of the severity of ground shaking and changes to be detected in local effects caused by soil conditions. The damage level was strongly influenced by the history of the structure (age and effects of previous earthquakes), the type of structure, the wall density, and the kind of soil.

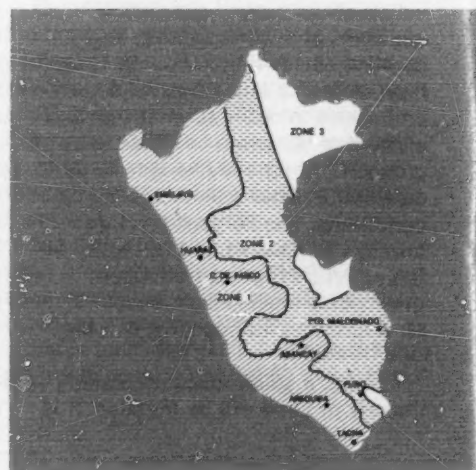
In 1982, a seismic-zonation study of the city of Lima will be initiated. It is

planned to carry out a preliminary vulnerability study of the entire city. Concurrently, soil, geologic data, and geophysical data will be acquired for three of the districts most damaged by historical earthquakes. An effort will be made to obtain the necessary soil information for two- and three-story constructions. A number of trenches and shallow borings are being considered. SH-wave and P-wave propagation velocity measurement will be made in borings and along short refraction profiles. At the same time, data for soil amplification-spectra studies will be gathered using natural events recorded on digital systems. This information will provide a constraint to the spectral response computations for dynamic models of soil at low levels of strain.



The 1977 official seismic zoning map of Perú. Zones 1, 2, and 3 shown in the map imply high, medium, and low seismic-active regions in Perú.

In summary, a great deal of work has been done in developing and implementing a methodology for seismic microzonation in Perú with very limited funds, manpower, and facilities. The progress made has only been possible thanks to the continuous support of the OAS multinational programs, the encouragement and technical assistance of Survey scientists, and the economic support of the Peruvian Government.



Progress of the Seismological Program in El Salvador

By Maximiliano A. Martínez,
Center for Geotechnical Investigations,
Ministry of Public Works,
San Salvador, El Salvador

Introduction

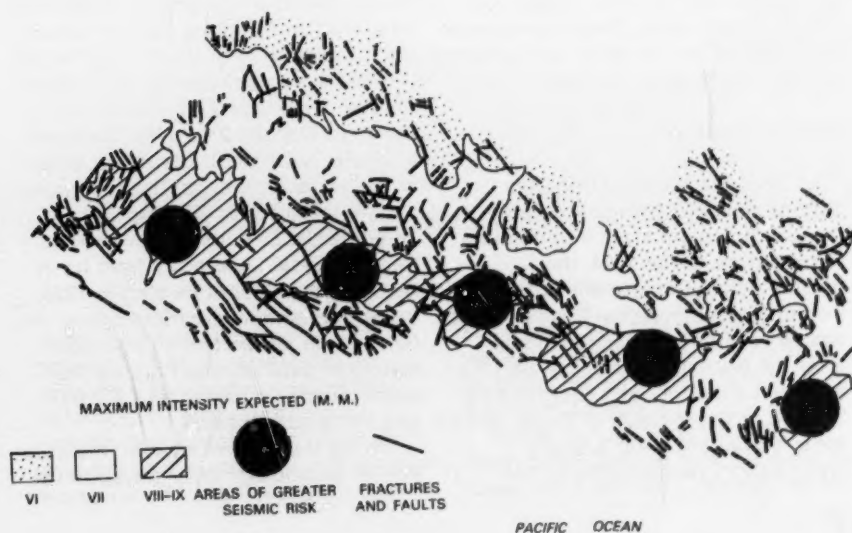
El Salvador is located in Central America at the axis of geographical coordinates 14° north latitude and 89° west longitude. Situated inside the circumpacific "ring of fire" it is thus vulnerable to sudden earthquakes and volcanic eruptions.

Since 1520, El Salvador has sustained approximately 40 destructive earthquakes, an average of one earthquake every 11.4 years. The interval of time between earthquakes during the centuries, however, has been variable.

For instance, given the importance of San Salvador as a city since the beginning of the 16th century, it shows historically that over any 100-year interval, there have been four catastrophic earthquakes in the region. During the 20th century, there have been already three large earthquakes in 1917, 1919, and 1965. If a recurrence of four earthquakes per century is a valid premise, then one may expect another large destructive earthquake before the end of this century.

In the following sections, a summary of the seismological programs in El

Preliminary seismic-zoning map of El Salvador.



Salvador, their present status, and programs proposed for the future are discussed.

Historical background

The first contacts with seismology in El Salvador go back to the late 19th century when a special department to be in charge of this discipline was added to the Instituto Nacional, a government educational center. Subsequently, by a Presidential Decree on October 25, 1900, the Astronomical and Meteorological Observatory was created with the purpose of establishing a scientific organization dedicated exclusively to geophysical and astronomical investigations. Since February 25, 1918, the seismological branch developed its own role by establishing the National Seismological Observatory which prevailed for the next 10 years. In 1928, it was reorganized and placed under the Meteorological Observatory to form the Observatorio Nacional de San Salvador.

The first seismographs were of the Ewing duplex-pendulum type, acquired in 1896, and were installed at different locations in the country. During the course of the years, these instruments were phased out; in 1930, two Wiechert seismographs were installed.

Present situation

In 1955, the National Geological Service was established incorporating the seismological station in this new organization. Since 1964, the Seismological Department of the Center for Geotechnical Research has been in charge of seismic studies, after the National Geological Service and the Laboratory and Experimental Section of the Ministry of Public Works were restructured into a single organization. Responsible for the

analysis of all the seismograms recorded in the country, the Seismological Department has four seismic stations.

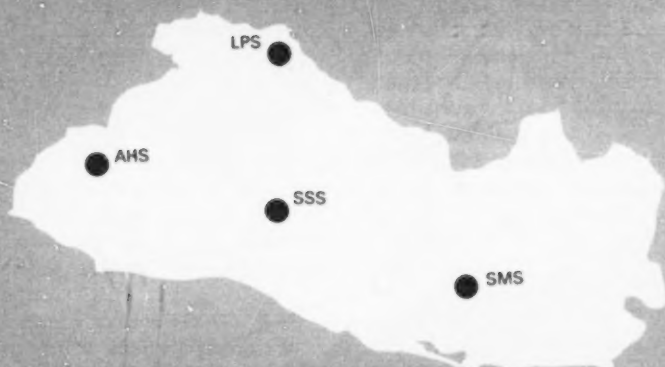
In 1964, the U.S. Coast and Geodetic Survey installed a Montana-type accelerometer in San Salvador (SSS). In 1965, 3 additional accelerographs and 20 seismoscopes were deployed in the city of San Salvador, and 5 seismoscopes were installed in the cities of Ahuachapán, Santiago de María, La Unión, and at the Cinco de Noviembre dam.

Since 1962, the La Palma Station Worldwide Standardized Seismograph Network (WWSSN) was started with the close collaboration and valuable assistance of the U.S. Geological Survey. The preliminary determination of epicenters (PDE) issued by the Survey has aided our national efforts in earthquake location and these data have been integrated into our seismological bulletins.

Research programs

In discussing the progress of our seismological research in El Salvador, two important periods of time can be recognized; the first period involves the beginning of seismological studies in the country; the second period involves present-day investigations. During the time of Dario Gonzalez, former Professor of Geophysics at the National Institute, Santiago I. Barberena, Director, at various times, of the Astronomic and Meteorological Observatory and Jorge Larde, Director of the National Seismological Laboratory from its inception in 1918 until he died in 1928, made outstanding contributions to the field. Larde left behind an abundant historical data set and his own field observations on earthquake studies and volcanic eruptions.

During the second interval, the direction of seismology in El Salvador has



Seismographic stations in El Salvador.

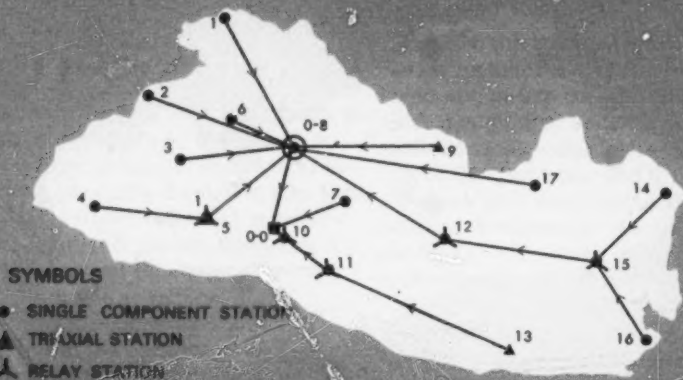


Strong-motion stations in El Salvador.

been toward modernization. The sophistication of present-day instruments has made possible the recording of local events below magnitude 3; programs of data processing and analysis have permitted an adequate definition of hypocenters

since 1962, and this has been a valuable addition to the regional seismic catalog of this Central American country.

Rudolf Schulz, Director of the Seismology Section in El Salvador between 1953 and 1967, reported on the



Seismic-telemetric project of El Salvador.



Strong-motion instruments in the metropolitan area of San Salvador.

results of research carried over a period of 10 years in the *Bibliographic Bulletin of Geophysics and American Oceanography* in 1963.

Using seismic information already published and that being accumulated by our Institute, an epicenter map of the Republic has been prepared for the period 1958-75. Analysis of this map is helping to delineate the area of subduction between the Cocos and Caribbean Plates and other seismic zones in El Salvador.

Besides the routine work of data processing and analysis being performed at the Institute, some new activities have been started since 1975 which have focused on seismic and volcanic risks. In these programs, historical aspects have been included that have resulted in the development of a seismic, and eruptive, chronology for the Republic of El Salvador, beginning in 1520. Historical data on earthquakes provided the first map of seismic zonation in our territory; the map was prepared by Schulz in 1964.

Data taken from our seismology bulletins have made it possible to obtain a sample of intensity for a period of 22 years, 1953-75, for the Metropolitan Area of San Salvador. This data base is also being used to construct a seismic zoning map of El Salvador which will be used in conjunction with the building code to provide safer guidelines in construction practices.

An urban planning study of the city of San Salvador was made by the German Geological Mission which was stationed in our country during the years 1967-71. One of the purposes of the German mission was to construct a national geological map of our country. Of particular interest was the mapping of the subsoil geology in areas where development of urban projects was taking place. This opportunity allowed us to prepare a microzonation map of the

metropolitan area of San Salvador which shows in preliminary form the seismic intensity changes that the different lithological units would experience. Preliminary fault traces are also shown.

Studies have also been conducted on the geological hazards for a radius of 200 km around San Salvador. Even though a strict monitoring of the volcanoes is not kept, any phenomenon of this type is studied, as was the case with the San Miguel Volcano that erupted on December 2, 1976. This eruption was classified as an eruption of the central crater type without exterior emission of lava cinders; after crystallization of the lava, the configuration was that of a cinder cone in the middle.

Future programs

Because of rural and urban population growth and industrial expansion, earthquakes present a daily risk. This demands the necessity of carrying out adequate seismic studies. Recent progress in seismic-detection systems and our interest in keeping up-to-date in seismological investigations have justified renovation of our present equipment. It has been decided to install a system that has the high standards demanded by the state-of-the-art technological advances.

A project has been considered which will involve the installation of a seismic telemetry network that covers all the national territory and which will expand the instrumental network to record strong motions. The design of the new seismological telemetry network has been planned according to the needs for seismicity studies in our country. It will require 17 remote stations, 3 of them with 3 component instruments, and a central recording station located at our facilities in the capital city.

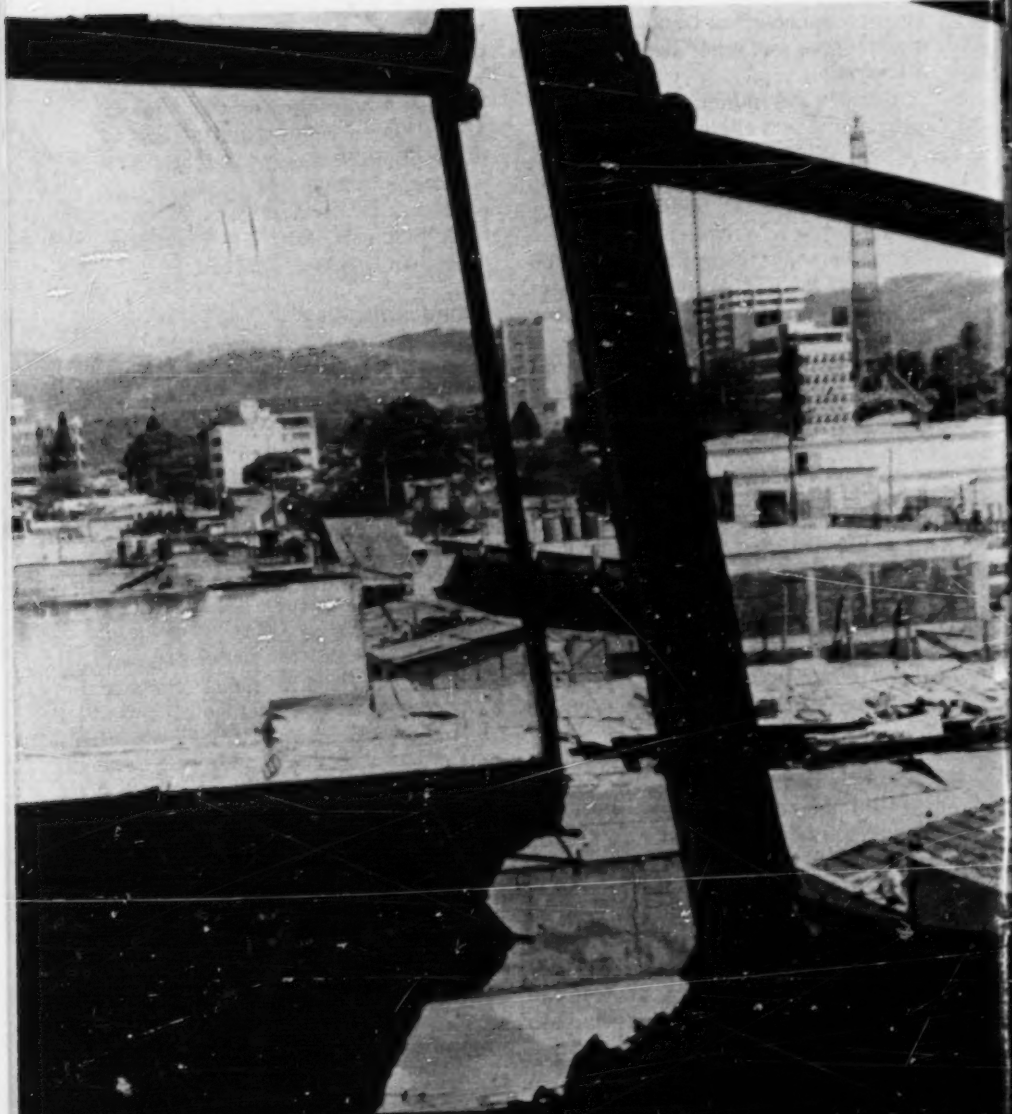
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View out of the third-floor window of the Hotel Terminal, Guatemala City, which collapsed after the 1976 Guatemala earthquake. (Photograph by A. F. Espinosa.)

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March-April 1982, Volume 14, Number 2

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Earthquake Information Bulletin



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Cover: Volcanologists from the U.S. Geological Survey's Hawaiian Volcano Observatory using a thermocouple probe to measure the temperature of an advancing toe of "pahoehoe" lava flow erupted from Kilauea's east rift zone in 1973. Measured temperature was about 1,130 °C. (Photograph by Robin Holcomb.)

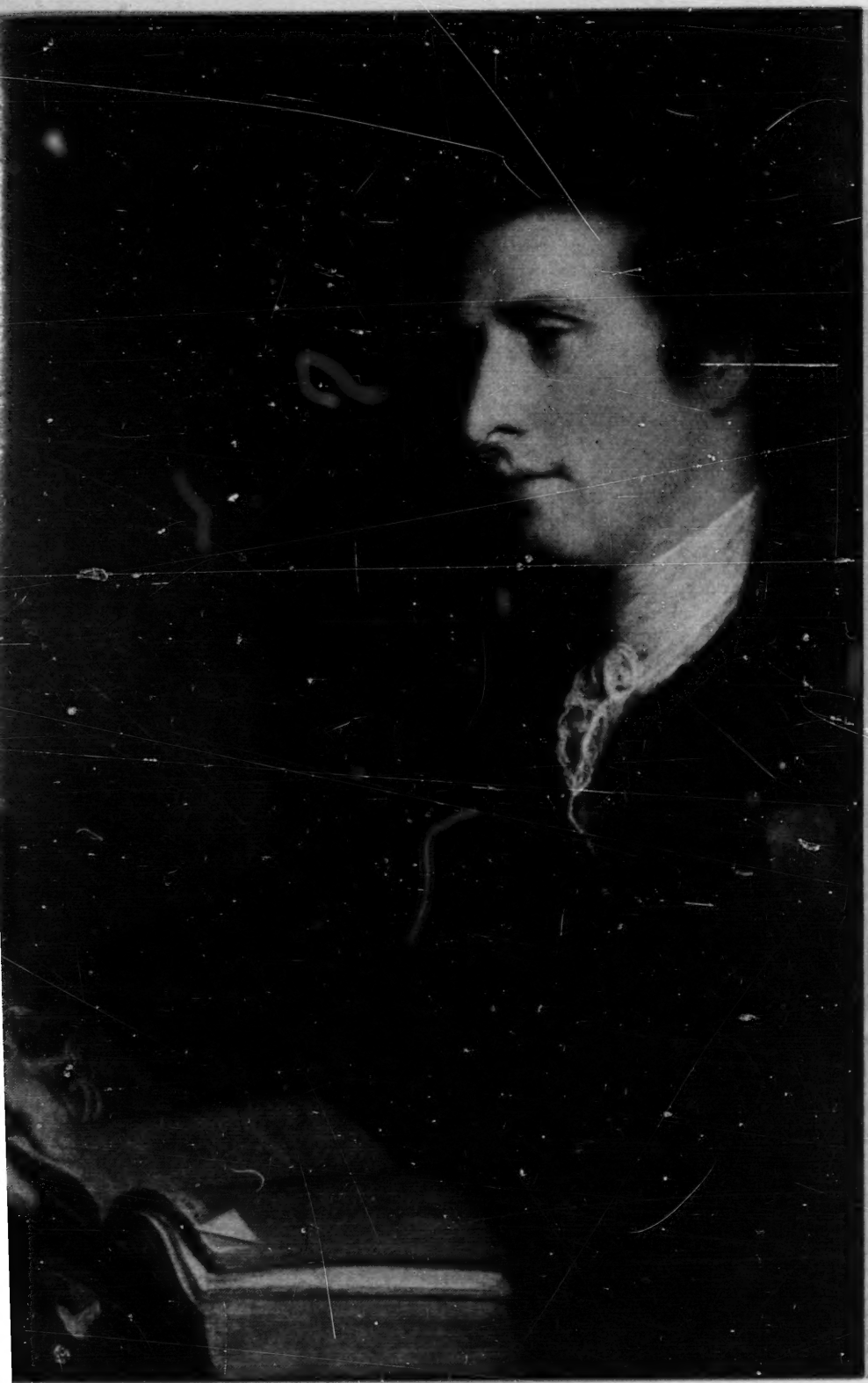
Sir William Hamilton— Pioneer Volcanologist

By John Guest,
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Mill Hill Park,
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In 1764, Sir William Hamilton, at the age of 34, accepted the post of British Ambassador to the Court of Naples in Italy. It was the middle of a century when men of learning in Europe collected, cataloged, and described objects and phenomena from the world about them to show the order of nature and to preserve the past. For a man of Sir William's profound curiosity, Naples was an ideal place to be based. He was surrounded by the remnants of Greek and Roman cultures; the exciting excavations at Pompeii and Herculaneum were in their early days; the active volcano of Vesuvius towered majestically above his home; and tremors and earthquakes were considered by the locals as normal events in their lives.

Hamilton's diplomatic duties were far from arduous, and he rapidly settled down to the collection of vases and other antiquities; some of these came from Pompeii and Herculaneum. In 1772, he sold his collection to the British Museum where it became the basis for the Departments of Greek and Roman Antiquities. He prepared four lavish volumes illustrating the collection; drawings from these inspired Josiah Wedgwood in the design of his early vases. It is sad that a second vase collection was lost when the ship carrying it, *The Colossus*, was wrecked. Only recently, the collection was recovered from the sea floor, and many of the pieces were reconstructed, using drawings made of the vases before they were shipped.

Portrait of Hamilton by Sir Joshua Reynolds (Toledo Museum of Art, Libbey Bequest). ►



Interest in volcanoes

The collection of antiquities took only a part of Hamilton's time; he was particularly interested in volcanic phenomena. He traveled widely in the Mediterranean, visiting many of the volcanoes, including Mount Etna and those in the Aeolian Islands. All his travels were meticulously documented; he described and attempted to explain everything he saw, and he even hired artists to sketch important findings and to illustrate his records. Many of the observations were published in 1772 in a book entitled *Campi Phlegraei*, to which he wrote a supplement in 1779.

Vesuvius

The volcano he knew and loved best was Vesuvius, and he became the leading expert of his time on this mountain. Quite naturally, he found himself acting as a guide to the constant stream of visitors passing through Naples on the Grand Tour. Famous and eminent people were introduced to the marvels of Naples by Sir William, including Emperor Joseph II of Austria and the German writer, Goethe. It is from some of their diaries and from Sir William's own writing that we know of his exploits. When Vesuvius was in eruption, he not only visited the flowing lava, but often insisted on going to the summit crater itself, despite violent explosions. During one particular visit in November 1765, falling bombs caused him to "retire with some precipitation" and made him "more cautious of approaching too near" in the future. Despite this experience, he ascended to the crater edge in March 1766 to spend the night observing the activity. Encouraged by this excursion, he spent another night at the crater shortly after, but this time he underestimated the situation; his companion was hit on the arm by a bomb, causing him severe damage and keeping him bedridden for 5 weeks. In 1794, another of Sir William's nerve-racking experiences occurred when a lava flow entered the sea. He decided to visit the flow front by boat but was forced to retire when his boatman pointed out that the pitch on the hull was melting and that the craft was beginning to sink. They were able to beach the boat nearby so that Sir William could continue his observations.





▲ Lava from Vesuvius being observed by Hamilton and the King of Naples. Painting by Pietro Fabris (British Museum).

Interest in seismology

Hamilton was also referred to as the Professor of Earthquakes by one English visitor. Although he is not so well known for his studies of earthquakes, he did produce *An Account of the Earthquakes in Calabria, Sicily, etc.*, in 1783. After the Calabria earthquakes in 1783, he drew an isoseismal map which may have been one of the first of its type.

Emma, Lady Hamilton

Hamilton's abilities as a scientist were recognized early when he was elected a Fellow of the Royal Society in 1766; but in the history books, he is better known for his collection of vases and for his second wife, Emma. His first wife died in 1782; and, in 1786, Hamilton's nephew sent his mistress, Emma, to stay

with his uncle in Naples. Emma rapidly became popular with Neapolitan society, and Hamilton, attracted by her beauty, intelligence, and vivacity, married her in 1791; she was more than 30 years his junior. Among other things, she became famous for her "attitudes," when she posed in the style and dress of various beauties depicted on Hamilton's ancient vases. Her fame spread throughout Europe, and Goethe described her performances as "like nothing you have ever seen."

Admiral Lord Nelson

Sir William's gentlemanly life in Naples was slowly brought to a halt by the naval battles between Britain and France in the Mediterranean; during this time, Emma played a prominent role in his diplomatic duties. She was also to meet Admiral Horatio Nelson, and there ensued between them one of the best-known love affairs in history. Having just won his famous victory in 1798 against the French at the Battle of the Nile, Lord Nelson was to become involved, through Sir William and Emma, in the escape of King Ferdinand and Queen Maria Carolina from Naples to Sicily. For this, Nelson was given the Dukedom of Brontë, a small town on the flanks of Mount Etna. Sir William was recalled to London, and he, Emma, and Lord Nelson traveled through Europe together. Once in London, Sir William settled down to a quiet life; it is ironic that, while he had derived great pleasure from Emma's lively personality in Naples, in London he began to find it tiresome and resented her constant entertaining and devotion to Lord Nelson. Hamilton died 3 years later in 1803. Although he left Emma well endowed, she spent lavishly. After Nelson's death on his day of victory at the Battle of Trafalgar in October 1805, she and her daughter by Nelson were to become paupers and eventually imprisoned for debt. Emma escaped to France where she died under miserable conditions. Should Nelson have lived, Emma might have well retired with him to his castle at Brontë in Sicily and spent the rest of her life within sight of one of her late husband's other loves, the volcano Mount Etna.



▲ *Vesuvius in eruption in 1794. Thought to be painted by Xarrerio Gatta (British Museum).*

Hamilton's contribution to volcanology

Sir William Hamilton's contribution to the earth sciences was a wide-ranging and important one. He died at the time that the ideas of Sir James Hutton on the uniformitarian character of nature were beginning to take a hold. Sir William lived at a time when catastrophism was an important way of thinking, and the environment in which he spent much of his life was



catastrophic. However, he never was a true catastrophist; he recognized that geological history was a long and continuous one, slowly evolving through the action of everyday processes such as volcanism. It was left to future workers such as Sir Charles Lyell to develop a coherent theory of geology that was augmented copiously by the observations of men such as Sir William Hamilton.

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◀ Admiral Horatio Nelson embarking from Portsmouth on the Victory before the Battle of Trafalgar, October 1805. Painting by A. C. Gow (National Maritime Museum, London).

Title page of Hamilton's *Campi Phlegrael*. ▼





Collapse of bank building in Varto, Turkey, after the earthquake of August 19, 1966. This was a three-story structure of reinforced-concrete post-and-slab construction with walls of brick and tile. Note the thick floor slabs and the steel rods in the collapsed post from which concrete has spalled. (Photographed by Robert E. Wallace.)

Bulletin Board—News in Brief

People in the Environment

The following is excerpted from Resources for the 21st Century: Summary and Conclusions of the International Centennial Symposium of the U.S. Geological Survey, by Frank C. Whitmore, Jr., 1982, Circular 857, 41 p. This is free on application to the Branch of Distribution, U.S. Geological Survey, 604 South Pickett Street, Alexandria, Virginia 22304.

Much as humans are to blame for the deterioration of their surroundings, certain natural phenomena also pollute and alter the environment and often threaten life itself. Conspicuous among these are volcanic eruptions and earthquakes. Landslides are a damaging and often dangerous phenomenon. Although ground subsidence and expansive soils are not usually

dangerous to human life, they can cause great damage to structures. Floods and droughts are widespread and serious threats. The effort to understand and to predict the occurrence of geologic hazards has led to an international cooperation in research that bodes well for the future.

Earthquakes

The worldwide nature of the earthquake threat has stimulated an improved exchange of information on methods of dealing with earthquakes. The highly successful international research programs now underway are excellent examples of international scientific cooperation. In the last 15 years, a highly effective interdisciplinary approach involving engineers, seismologists, geologists, sociologists, land-use planners, politicians, and financiers has developed. Although we have a long way to go, our confidence in our predictive capability has increased, as has the attention paid by governments to the recommendations of scientists. Such recommendations are not limited to earthquake prediction; more important at the present time, because they are better understood, are preventive measures such as earthquake-resistant design and land-use planning. It was pointed out during the Symposium that, especially in less well developed countries, a simple upgrading of craftsmanship in masonry work would perhaps do more to save lives than all our sophisticated and advanced technology combined.

In the U.S.S.R., seismic zoning, developed since 1930, is the basis of all state planning, design, and building operations. Detailed geologic investigations are required for sensitive projects such as hydrotechnical projects and nuclear power plants. Similar approaches are being developed in other countries.

All prediction and amelioration of earthquake activity must be based on fundamental scientific studies, and international cooperation is paying off in this regard. As one American worker said, work in Turkey may teach us more about the San Andreas fault than our studies in California will.

An important impetus to the improvement of earthquake prediction is its importance to less well developed countries, where

earthquake-proof construction and land-use planning procedures are too expensive to implement. In the People's Republic of China, tens of thousands of lives have been saved by successful earthquake predictions. In the U.S.S.R., several successful predictions have been made. Earthquake studies in California are being bolstered by studies of seismicity in other parts of the United States. Japan, like the People's Republic of China, has had excellent success in recognizing earthquake swarms.

In Japan, the Earthquake Research Institute of the University of Tokyo is working on quantified expression of earthquake prediction, giving a success rate that can then be used in calculating the cost of prediction. The cost of prediction as projected for the next 10 years is still only a fraction of a percent of the property damage caused by the 1923 earthquake. The percentage becomes even smaller when we consider how explosively the potential for disaster has been increased by the growth of urban populations.

As examples of current research programs, earthquake studies in the Andean region of South America and in Turkey were selected for detailed consideration by the Symposium.

A pilot study of Andean seismicity was proposed in 1973 and approved by the Organization of American States. Funds were provided to CERESIS, the Regional Center for Seismology for South America, to carry out the project in Bolivia, Colombia, Ecuador, and Peru and to produce preliminary seismotectonic and seismic risk maps. As the project nears completion, more than 30,000 seismic events occurring between 1471 and 1977 have been identified, and preliminary maps have been produced. Concurrently, scientists from Peru, Colombia, Ecuador, and Bolivia have collaborated with colleagues from France, the United States, and Canada on fundamental research into the nature of tectonic forces.

In Peru, the National Civil Defense Committee has appointed a scientific advisory group to evaluate hazard potential. This project includes consideration of landslides, mudflows, subsidence, rockfalls, tsunamis, earthquakes, and volcanoes. Effects of rainfall, electrical storms, freezes,

ocean currents, droughts, and pollution and other manmade hazards are also considered.

Turkey has begun earthquake-prediction studies within the framework of a research project sponsored by the U.S. Geological Survey. One of the most seismically active continental regions in the world, Turkey has a 2,000-year historical record of earthquakes. The Turkish program consists of (1) detailed geologic mapping of fault zones, (2) monitoring of microearthquakes, (3) measurement of ground deformation, and (4) assembly of earthquake statistics for risk analysis and for the location of seismic gaps along major fault lines. The most complicated and seismically important part of eastern Turkey has been mapped. Markers have been placed so that the network can be resurveyed to determine changes in the strain field near a plate boundary.

In the search for an understanding of tectonic processes, space technology offers the best way to measure global-scale deformation on such major faults as the North Anatolian fault in Turkey, the San Andreas fault in the United States, and the Alpine fault in New Zealand. The European Space Agency is formulating a plan to make a study of the North Anatolian fault, and the Andean countries are discussing with the National Aeronautics and Space Administration the possibility of participating in NASA's Geodynamics Program.

In earthquake studies, continuity is necessary, and international cooperation is important.

Volcanoes

As it has in earthquake studies, international cooperation in the study of volcanoes has greatly increased in recent years, again with the aim of being able to predict events. In discussions at the Symposium, two aspects of volcano studies emerged—adequacy of baseline geophysical data and the relationship between scientists and the public.

In terms of human safety, the critical decision in a period of volcanic activity is when to order evacuation of an area. The chances of correctly predicting an eruption

are greatly increased by baseline observations, such as those provided by a network of seismometers documenting upward movement of earthquake foci or by deformation studies designed to detect changes in the shape of a volcano.

Two recent eruptions in the eastern Caribbean exemplify the need for baseline data. In 1976, eruptions of steam and ash from La Soufrière volcano on the island of Guadeloupe, accompanied by hundreds of local earthquakes, seemed to presage a dangerous eruption. Tens of thousands of people were evacuated from the area for a period of several months. The eruption never occurred. During the long period of evacuation, scientists and authorities were uncertain about the significance of the volcanic events. In great part, this uncertainty was due to a lack of baseline data; knowledge of long-term changes in the volcano could have led to an estimate of the time of an eruption and of what type of eruption might take place.

In 1979, another Caribbean eruption occurred on the island of St. Vincent. This volcano, also named Soufrière, had, by contrast, been subjected to baseline geophysical studies. The temperature of the water in the crater lake had been monitored at regular intervals and found to be increasing. Tiltmeters installed 2 years before the eruption indicated that the volcano was swelling. Seismometers were in operation on and near the volcano. When the eruption came, it was so sudden that evacuation was immediate. But the baseline data were valuable in interpreting the course of volcanic activity after the first eruption and thus helped to determine when it would be safe to return the evacuees to their homes.

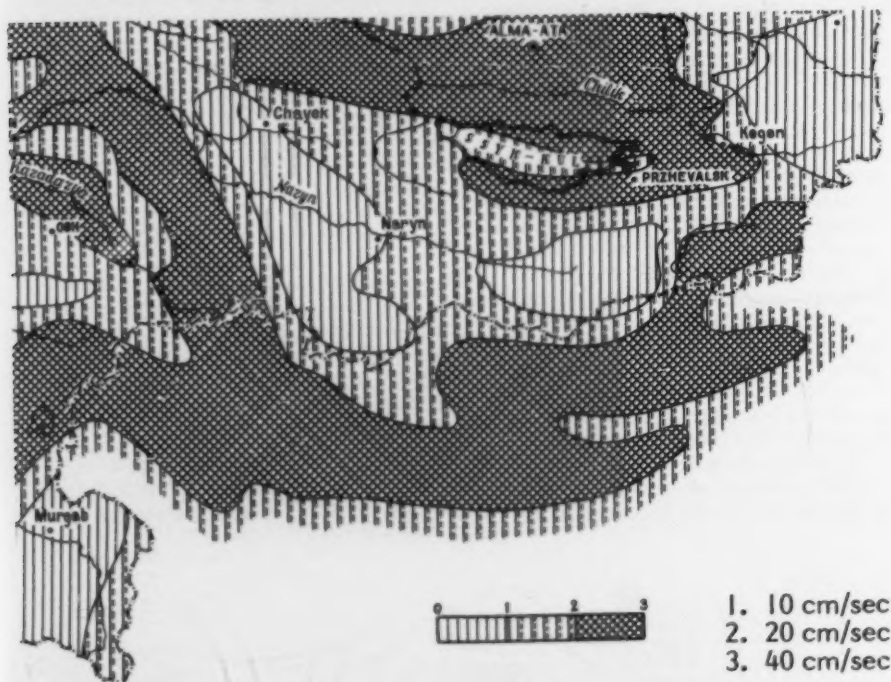
Coping with volcanic activity requires the combined efforts of scientists, engineers, and political authorities. In addition, the news media play a very important part in conveying information to the populace. The two Caribbean eruptions furnished contrasting examples of press relations. On Guadeloupe, the press corps was allowed almost unlimited access to the volcanologists, some of whom were in disagreement concerning interpretation of the observed

phenomena. Thus, at times, the disagreements, rather than what was happening at the volcano, became the news. In St. Vincent, on the other hand, the press was briefed by government representatives, who used information supplied by the scientists.

Informing the public concerning volcanic activity on a small island is, of course, far simpler than it would be in a large area such as the Western United States. The eruption of Mount St. Helens, which began several months after the International Centennial Symposium, exemplifies the need for dissemination of timely and accurate information and shows how it can be done on a large scale. The frequent release of up-to-date information was handled by a staff of information officers working with

the scientists. The scientists were available for press briefings as their work permitted; the information officers served as a continuing source of information.

Releasing information to the public is difficult because we do not know how best to help the public understand natural hazards, particularly when the inadequate state of our knowledge leads to uncertainty about the timing and course of hazardous events. Hence, it is encouraging that sociologists are making studies of people's response to news. These studies may lead to more effective policies concerning the timing and the manner in which possible impending hazards are announced and the best ways to impart the incomplete state of our scientific knowledge.



Seismic zoning map of the Pamir and Tien Shan mountain ranges in Soviet Central Asia, based on the maximum expected velocities of the ground motion. (Adapted from The Soviet-American Exchange in Earthquake Prediction, by Henry Spall and D. W. Simpson, 1981, U.S. Geological Survey Open-File Report 1150, p. 217.)

HAZARDS REDUCTION WORK: THE NEXT ERA

Text and illustration from Natural Hazards Observer (University of Colorado at Boulder).

Efforts in the last decade have done much to improve our tools for reducing the ill effects of natural and technological hazards. At the same time, a hearty generation of policymakers and users has emerged to wield those tools and put new ideas into practice. However, losses on many fronts continue to increase, and this Nation and all other nations face an era of unparalleled calamities. Disaster losses, always to be lamented, will be even more difficult to accept in the future given that the means are available to reduce them.

We have entered an era that demands serious work on hazards reduction. It is one in which action and application of knowledge deserve top billing, and several shifts in emphasis are therefore needed. First, discipline-bound singular solutions must be abandoned; for example, the quest for the perfectly engineered dam is dangerous if we ignore the need for an accompanying warning system to be used when the engineered solution fails. Second, singular hazard problem definition must be discouraged. Increased losses may result from restricting development in high seismic risk areas, for instance, if attention is not paid to whether that policy encourages building on stable slopes prone to mudflows.

Third, the existence of two classes of hazards professionals (researchers and users) may be a major constraint to ac-

complishment. The language of science rarely informs decisionmakers, nor does it give people in action roles the ammunition they need to do battle within political systems. Work would be more usable if done by teams from both classes of our now rigidly stratified field of endeavor. Fourth, the definition of research as knowledge "obtaining" but not necessarily "applying" is antiquated. Good research must be both. Fifth, acknowledged accomplishments may be a major constraint to progress; for example, there are many less than state-of-the-art regulations on municipal and State books. Despite the fact that the regulations may once have been milestones, we must resist the temptation to label them final solutions. And finally, we must stop ignoring major segments of society in our loss-reduction work and, instead, push for their active participation in hazards planning and decisionmaking. Our emphasis on the public sector and the mitigation of direct disaster losses has left much undone in the private sector and accomplished little towards the mitigation of secondary social and economic impacts.

The rich advances in knowledge made in the last decade, although admirable, are actually a fiat for concerted action in the 1980's. The hardest work is yet to be done, and we must be more clever and energetic than we have ever been.

Dennis S. Milet
Department of Sociology
Colorado State University



Cascades Volcano Observatory Named for David Johnston

On January 12, 1982, Dallas Peck, Director of the U.S. Geological Survey, designated the Survey's volcano field office in Vancouver, Washington, as the David A. Johnston Cascades Volcano Observatory. This action makes the new facility in name, as well as in fact, the sister observatory of the Hawaiian Volcano Observatory. U.S. Geological Survey Professional Paper 1250, the scientific reports on the Mount St. Helens eruptions, has been dedicated in honor of Dave Johnston, and last year the Survey named one of its new inshore craft the R/V DAVID JOHNSTON.

In his letter giving the news of his action to Thomas and Alice Johnston, Dave's parents in Oaklawn, Illinois, the Director recalled for them how Dave had been

held in highest esteem by his colleagues in the volcanologic community, both inside and outside the Geological Survey. Being a volcanologist myself and having spent two years on the staff of the Hawaiian Volcano Observatory, I can truly appreciate the scientific contributions David made before his brilliant career was cut short by his untimely death. I cannot think of a more fitting and lasting tribute to David than naming the Cascades Volcano Observatory after him—a facility dedicated to the type of research David loved and pursued with vigor and innovation.

Earthquake History of California Before 1900

Toussou R. Topozada, Charles R. Real, and David L. Parke of the California Division of Mines and Geology, Sacramento, have completed a 3-year project to clarify the earthquake history of California for the period before 1900. One hundred and thirty seven earthquakes were studied. Nearly 12,000 newspaper issues were searched for earthquake reports, and about one-quarter of the issues searched have provided earthquake reports. The strength and spatial distribution of the reported earthquake effects were used to estimate the magnitude

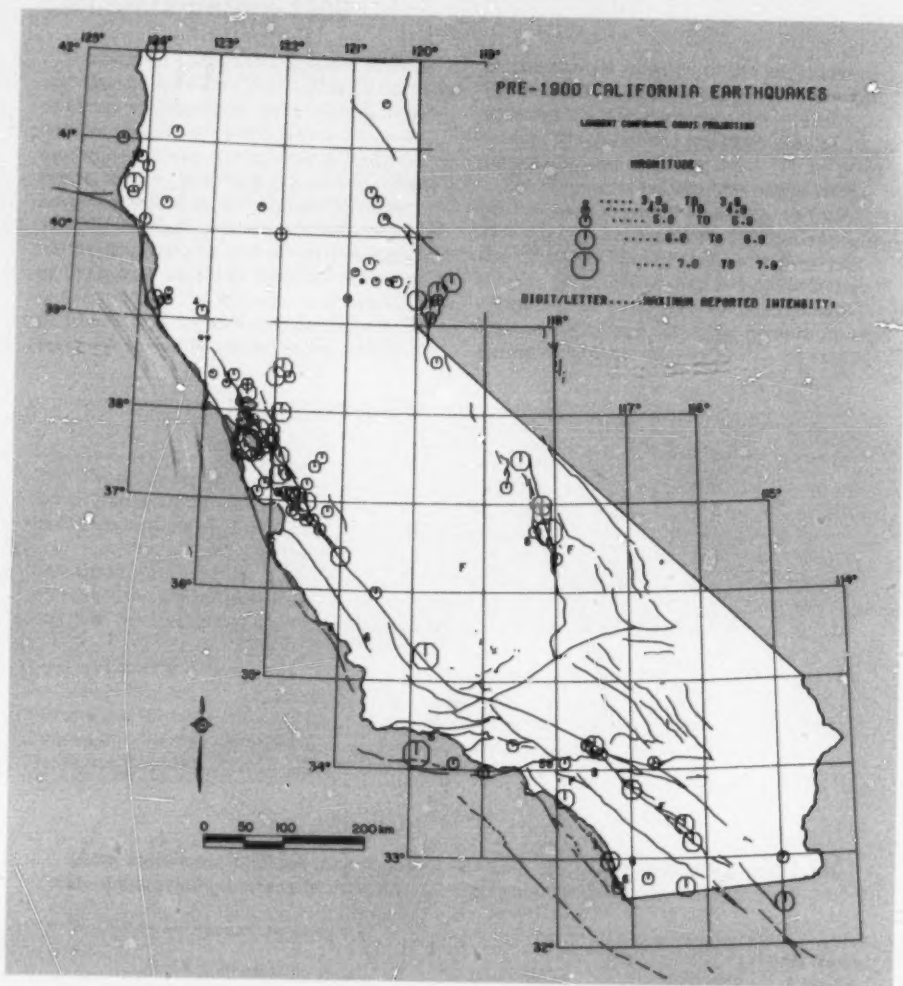
and epicentral location of the earthquakes. The intent was to provide isoseismal maps showing the distribution of the intensity reports which control the estimates of magnitude and epicenter.

The epicentral distribution of pre-1900 earthquakes is generally similar to that of 20th century earthquakes. Comparison with the Epicenter Map of California (Real and others, 1978), which displays post-1900 epicenters, shows that the following areas were more strongly affected by earthquakes before 1900 than after 1900:

Area	Date	Magnitude	Maximum Intensity
San Diego County	February 24 1892	6.7	VIII-IX
Santa Barbara Channel	December 21 1812	7.1	VIII
Los Angeles County	December 8 1812	6.9	VII
	February 9 1857	7.9	IX +
Inyo County	March 26 1872	7.8	IX +
Western Stanislaus County	April 10 1881	5.9	VI
East San Francisco Bay	June 1836	6.8	VII-IX
	October 1868	—	—
Yolo and Solano Counties	April 19 1898	6.4	IX
San Pablo Bay	March 31 1898	6.2	IX
Mendocino County	April 15 1898	6.4	IX
Lassen and Plumas Counties	January 24 1875	5.8	VII
Del Norte County	November 23 1873	6.7	VIII

Other significant findings include information suggesting surface faulting that was not previously recognized during the following earthquakes:

Possible fault rupture	Date	Magnitude	Maximum Intensity
San Andreas, Santa Cruz County	October 11-31 1800	—	VII
	October 8 1866	6.3	IX
San Andreas, Monterey County	February 2 1881	5.6	VIII
Near Carson City, Nevada	June 3 1887	6.3	VIII
Antioch, Contra Costa County	May 19 1889	6.0	VIII
Near Jacumba, San Diego County	February 24 1892	6.7	VII-IX
Between Vacaville and Winters, Solano County	April 19 1892	6.4	IX
Calaveras, Santa Clara County	June 20 1897	6.2	VIII-IX
San Jacinto, Riverside County	December 25 1899	6.6	IX



Epicenters of pre-1900 California earthquakes.

Serious doubts have been raised as to the occurrence of an earthquake reported to have caused fault rupture on the Big Pine fault in southern California in 1852. The 1869 earthquake that was reported to have ruptured the Olinghouse fault in western Nevada, about 20 miles to the northeast of Reno, appears from the felt effects to be centered about 10 miles south of Reno. The 1875 earthquake that was reported to have ruptured the Mohawk fault zone in northeastern California appears from the felt effects to be centered about 30 miles to the north, near Honey Lake Valley.

Some earthquakes that were previously thought to be destructive were proven to be small, and other large earthquakes were identified for the first time.

California Moves on Earthquake Safety

Three new pieces of legislation sponsored by the California Seismic Safety Commission will make major contributions toward earthquake safety throughout the State. The California Earthquake Education Act of 1981 (S. 843) provides \$250,000 for public education programs about earthquake preparedness and response. The projects will be developed during the next 2 years by the Lawrence Hall of Science, University of California at Berkeley, under the direction of the Commission. After being tested in communities and schools in Alameda, Contra Costa, and Los Angeles Counties, the programs will be available for use statewide.

Under provisions of the Mobile Home Safety Act (S. 360), mobile-home bracing devices must be State-certified before they may be marketed. Manufacturers now must subject the product to physical testing to demonstrate that it meets engineering standards set up by the State Department of Housing and Community Development. This should help protect owners of mobile homes who in the past have been faced with a bewildering array of devices from which to choose, each accompanied by its manufacturer's claim of adequacy to withstand earthquake shaking.

Another Commission bill, expected to become law early in 1982, will provide for improved enforcement of seismic standards for hospital construction by the State.

For more information, contact
California Seismic Safety Commission
1900 K Street
Suite 100
Sacramento, California 95814
(916) 322-4917

Centenary of the Death of Charles Darwin

In April 1882, Charles Darwin died at his home in Downe, Kent, a village outside London. A week later, he was buried with full honors in Westminster Abbey, the place that England reserves for its heroes.

In celebrating the death of the 19th century's most renowned scientist, we celebrate the person who originated the theory of natural selection, one of the foundation stones of modern biology. Darwin's earliest scientific efforts were in geology, where he helped develop important ideas about the mobility of the Earth's crust.

Darwin's innovations in geology came from his nearly 5 years aboard HMS *Beagle*, sent by the Royal Navy to chart the west coast of South America. The *Beagle's* captain, Robert FitzRoy, wanted a gentleman to share his meals during the long cruise. By tradition, the captain of a naval vessel dined alone, and the aristocratic and authoritarian FitzRoy, veteran of the *Beagle's* previous cruise, knew how stressful the 5 solitary years might be. Thus Darwin came aboard the *Beagle* as the Captain's guest.

His voyage aboard the *Beagle* transformed Darwin, an amiable young man with no definite career in mind, into a dedicated scientist. Guided by Charles Lyell's *Principles of Geology*, whose successive volumes the voyaging Darwin received as they were published, the young naturalist developed a new understanding of the role of subsidence and uplift in reshaping the face of the Earth.

From Santiago, in the Cape Verde Islands, to St. Paul's Rocks, a bare outcrop in the middle of the Atlantic, around South America to the Galapagos Islands, then home by way of Tahiti, New Zealand,

Australia, Mauritius, Capetown, St. Helena, Ascension, and the Azores, Darwin applied his keen intellect to observing the geology and to thinking about how to explain it.

In Concepción, Chile, he experienced the earthquake of February 20, 1835. He noted that the earthquake raised the land by several feet and that it coincided with volcanic eruptions in the Andes and beneath the sea near the island of Juan Fernandez. To these observations, he joined others made in the Andes where thousands of feet of sediments alternated at high altitudes with volcanic lavas.

On his return to London, Darwin industriously began to work himself into a position of standing among "scientific men," as they were then called. His earliest reports to the Geological Society of London brought him great attention, and he soon became its Secretary. In 1839, he published his first book, the *Journal of Researches into the Geology and Natural History of the . . . Countries Visited by H.M.S. Beagle*, one of the most famous travel narratives ever to appear. He followed it with three books of geology: *Coral Reefs* (1842), *Volcanic Islands* (1844), and *Geological Observations on South America* (1846). By this time, the living world had replaced the rocks as his principal concern, and Darwin eventually was to become known for his zoology as he searched for clues to the origin of species. The geological ideas he had pioneered so brilliantly he left to others to develop further.

To commemorate the centennial of Darwin's death, Great Britain has issued a series of special stamps.

Harold Burstyn



Earthquakes

September-October 1981

By Waverly J. Person,
National Earthquake Information Service,
U.S. Geological Survey,
Denver, CO

There were three major earthquakes (7.0-7.9) during this reporting period. The first and largest was a magnitude 7.7 on September 1 in the Samoa Islands region in the South Pacific. A magnitude 7.2 occurred on October 16 off the coast of central Chile. The third, on October 25 in Michoacan, Mexico, had a magnitude of 7.1. Two earthquakes which caused fatalities were in Kashmir and Venezuela, on September 12 and October 18. They had magnitudes 6.1 and 5.4, respectively.

In the United States, a number of earthquakes were experienced during the 2 months, but caused only slight damage. The largest was a magnitude 5.9 on September 4 in southern California.

Samoa Islands

These islands were rocked by a major earthquake on September 1. The magnitude 7.7 earthquake was located about 1,800 km northeast of Brisbane, Australia, near western Samoa. The quake was felt strongly in the area, but no damage was reported. A local tsunami was recorded at Pago Pago (9.5 in peak-to-peak).

California

As usual, this State experienced a number of earthquakes. The largest during this reporting period was on September 4 at 8:51 a.m. P.d.t. in the southern part of the State. This earthquake had a magnitude of 5.9 and was located about 50 mi southwest of Los Angeles and about 18 mi north of Santa Barbara Island. Some minor damage was reported in the Los Angeles area and on Catalina Island; this damage registered VI on the Modified Mercalli Intensity Scale (MM). The shock was felt throughout much

of southern California from San Luis Obispo to the Mexican border. A number of aftershocks have followed. The largest were on October 23 at 10:28 a.m. P.s.t. and 12:15 a.m. P.s.t. Both shocks had magnitude 4.6. MM V effects were experienced at San Pedro, Artesia, and Mission Hills. The quake was also felt in Los Angeles, Orange, Riverside, and Ventura Counties.

On September 16 at 5:41 a.m. P.d.t., the northern part of the State experienced a sharp earthquake. The quake had a magnitude of 4.5 and was located about 12 mi south of Petrolia near the coast. MM V effects were experienced at Weott and Whitethorn, and MM IV effects in the areas of Eureka, Garberville, Leggett, Loleta, Miranda, Redway, and Rio Dell.

On September 30 at 4:53 a.m. P.d.t., the east-central part of the State was shaken by a moderate earthquake. The magnitude 5.8 quake was located about 80 mi north-east of Fresno in the Mammoth Lakes area near the Nevada border. Some slight damage (MM VI) was reported in the Mammoth Lakes area. The quake was felt throughout a wide area of California from Sacramento to Bakersfield and in parts of Nevada. A number of aftershocks have followed. The largest was a magnitude 4.8 at 6:06 a.m. P.d.t. about 1 hour and 12 minutes after the main shock.

Washington-Oregon Border

The southwestern part of Washington experienced a small earthquake on September 6 at 12:35 a.m. P.d.t. The magnitude 3.1 quake was located about 12 mi southwest of South Bend near the Oregon border. Intensity MM IV effects were experienced at Oysterville, and MM III at Tokeland, Wash.

Kashmir

The northwestern part of this State of Pakistan was struck by a devastating earthquake on September 12. The magnitude 6.1 earthquake was centered about 35 mi southwest of Gilgit. Two hundred twelve people were killed, at least 17 people are missing, 2,000 people were injured, and extensive damage occurred mostly in the Darle Valley area. Some of the villages were completely destroyed. The earthquake was felt in the Peshawar and Rawalpinda, Pakistan, area, but there were no reports of damage. A number of aftershocks have followed, two having magnitudes of 4.9 and the rest in the 4.0 range. No additional damage was reported.

South Dakota

A small, but rare, earthquake occurred in the southwestern part of this State on September 13 at 4:16 p.m. m.d.t. The magnitude 3.4 quake was located about 95 mi southeast of Rapid City in Bennett County near the Nebraska border. MM IV effects were experienced at Martin and Vetat.

Colorado

The north-central part of this State experienced a small earthquake on September 16 at 1:59 p.m. m.d.t. The magnitude 2.1 tremor was located in the Commerce City-Thornton area and was felt by a few people in that area.

Hawaii

A number of earthquakes were experienced in this State during this reporting period. The largest were on September 22 at 4:50 a.m. h.s.t., October 4 at 3:42 p.m. h.s.t., and October 27 at 11:34 p.m. h.s.t. These earthquakes had magnitudes 4.0, 4.2, and 4.2, respectively, and were located on the southeastern part of the island. The quakes were felt on the southeastern part of the island, but there were no reports of damage.

Utah

The northeastern part of this State experienced a minor earthquake on September 21 at 2:02 a.m. m.d.t. The

magnitude 3.6 quake was located about 70 mi southeast of Provo. The tremor was felt in the areas of East Carbon and Sunnyside (MM IV).

Idaho

The southeastern part of this State was shaken by a minor earthquake on September 29 at 10:18 p.m. m.d.t. The magnitude 3.9 earthquake was centered about 55 mi southeast of Pocatello near the Wyoming border. MM IV effects were experienced at Bern, Dingle, and Paris. The quake was also felt with lesser intensities in the southeast corner of the State.

Nevada

The west-central part of this State experienced a minor earthquake on September 29 at 8:14 p.m. P.d.t. The magnitude 3.3 earthquake was located about 12 mi east of Carson City and was felt at Carson City and Virginia City.

Wyoming

A small earthquake occurred in Yellowstone National Park on October 8 at 8:50 a.m. m.d.t. The magnitude 3.0 tremor effect was located in the vicinity of Old Faithful and was felt in that area.

Chile

The central part of this country was shaken by a major earthquake on October 15 at 11:26 p.m. The magnitude 7.2 earthquake was centered about 120 mi west of Santiago. One person was killed in an automobile accident; there were no other casualties or damage reported. The shock was felt strongly throughout central Chile.

Colombia-Venezuela

A moderate, but damaging, earthquake occurred on the Colombia-Venezuela border on October 18. The magnitude 5.4 earthquake was located about 250 mi north of Bogotá in the vicinity of Cucuta and San Cristóbal, Venezuela. Seven people were reported killed, and damage was experienced in Cúcuta, Colombia. In San Cristóbal, Venezuela, eight people were reported killed, and heavy damage occurred. Landslides were also reported in the San

Cristóbal area. At least 100 people were reported injured in the two countries. The quake was felt strongly in northeastern Colombia and western Venezuela.

Mexico

The southern part of this country was struck by a major earthquake on October 24 at 9:22 p.m. The magnitude 7.3 earthquake was centered about 200 mi southwest of Mexico City in southeastern Michoacán near the Pacific coast. One person was killed, 11 people were injured, and some damage occurred in Mexico City. In Michoacán, 2 people were killed, 17 were injured, and extensive damage was experienced. The earthquake was felt strongly throughout southern Mexico. Some aftershocks have followed, but none were large enough to cause additional damage.

Southern New England

This area experienced a minor earthquake on October 21 at 12:49 a.m. e.s.t. The

magnitude 3.8 earthquake was located about 20 mi southeast of New Haven, Conn., in Long Island Sound, an area where very few earthquakes have been located. MM V effects were experienced in the New Haven-New London, Conn., area. It was also felt on Long Island, N.Y.

U.S. Activity*

Alaska	4
California	37
Colorado	1
Connecticut	1
Hawaii	10
Idaho	1
Nevada	2
New York	1
South Dakota	1
Utah	1
Washington	1
Wyoming	1
Total	61

*Felt earthquakes are reported from many sources.

Preliminary Locations

Date	Origin time		Region	Coordinates		Depth (km)	Magnitude
				Latitude	Longitude		
Sept. 1.....09	29	32.4	Samoa Islands region.	15.0 S	173.2 W	33	7.7 M _S
Sept. 4.....15	50	50.3	Southern California	33.7 N	119.1 W	5	5.9 M _S
Sept. 6.....19	34	5.9	Washington-Oregon border region.	46.7 N	123.9 W	35	3.1 M _L
Sept. 12.....07	15	54.0	Northwestern Kashmir.	35.7 N	73.5 E	33	6.1 m _b
Sept. 13.....22	16	29.9	South Dakota	43.0 N	101.8 W	5	3.4 m _b L _g
Sept. 16.....12	41	15.0	Near coast of northern California.	40.1 N	124.3 W	5	4.5 M _L
	19	56	Colorado	39.9 N	105.0 W	5	2.1 M _L
Sept. 21.....08	01	33.0	Utah	39.6 N	110.4 W	2	3.6 M _L
Sept. 23.....02	50	23.7	Hawaii	19.3 N	155.1 W	10	4.0 M _L
Sept. 30.....03	14	03.2	Nevada	39.1 N	119.6 W	5	3.3 M _L
	04	17	Eastern Idaho	42.5 N	111.2 W	5	3.9 M _L
	11	53	California-Nevada border region.	37.6 N	118.9 W	5	5.9 M _L
	13	06	do	37.6 N	118.9 W	5	4.8 M _L
Oct. 5.....01	42	28.0	Hawaii	19.3 N	155.5 W	29	4.2 M _L
Oct. 8.....16	49	32.6	Yellowstone National Park, Wyoming.	44.2 N	110.9 W	5	3.0 M _L
Oct. 16.....03	25	42.1	Off coast of central Chile.	33.1 S	73.1 W	32	7.2 M _L
Oct. 18.....04	31	02.8	Venezuela	8.1 N	72.5 W	56	5.4 m _b
Oct. 21.....16	49	06.7	Southern New England.	41.2 N	72.6 W	6	3.8 m _b L _g
Oct. 23.....17	26	16.9	Southern California.	33.6 N	119.0 W	12	4.6 M _L
	19	15	do	33.6 N	119.0 W	6	4.6 M _L
Oct. 25.....03	22	15.4	Michoacán	18.0 N	102.1 W	33	7.3 M _S
Oct. 28.....09	33	32.3	Hawaii	19.4 N	155.3 W	33	4.7 M _L

*Magnitude from surface waves.
 *Richter magnitude

*Magnitude from body waves.
 *Magnitude from Love waves.

Announcements

Seismological Society of America

The 1982 meeting of the Eastern Section of the Seismological Society of America will be held at Airlie House, Warrenton, Virginia, from September 27 to 29, 1982. Abstract deadline is August 27. The meeting is being hosted by the U.S. Geological Survey, and the convenors are Robert M. Hamilton and Henry Spall [U.S. Geological Survey, 904 National Center, Reston, Virginia 22092, (703) 860-6575].

Conference on Earthquake Engineering

The Fourth Canadian Conference on Earthquake Engineering will be held in Vancouver, British Columbia, from June 15 to 17, 1983. Authors are invited to submit technical papers on fundamental, experimental, computational, and practical aspects of both design- and research-oriented projects. Areas of particular interest are as follows: (1) seismology and ground motion, (2) soils, foundations, and soil-structure interaction, (3) structures and structural dynamics, (4) site-specific applications of risk analysis,

and (5) code specifications and design applications. Papers describing the application of state-of-the-art procedures to major projects, such as nuclear powerplants, pipelines, large earth structures, LNG plants, and offshore structures, are especially welcome.

Abstracts of proposed papers of approximately 500 words should be submitted to Professor S. Cherry, Earthquake Conference, c/o Civil Engineering Department, University of British Columbia, Vancouver, British Columbia, V6T 1W5, Canada, no later than September 1, 1982. Final acceptance of papers will be based on a review of the complete manuscripts.

From the Bulletin Ten Years Ago

The March-April issue 1972 (Volume 4, Number 2) included items on:

- Forced vibration testing (building shaking).
- Strong-motion instruments for California's highway bridges.
- Earthquake hazards in the Seattle area.

Book Review

Volcanoes of the World. By Tom Simkin, Lee Siebert, Lindsay McClelland, David Bridge, Christopher Newhall, and John H. Latter. 1981. Hutchinson Ross Publishing Company, Stroudsburg, Pennsylvania. 240 p. (Distributed by Academic Press, 111 Fifth Avenue, New York, NY 10002; \$19.75)

This volume is the culmination of a 10-year effort begun in 1971 by the Smithsonian Institution in Washington, D.C., to compile systematically the record of volcanic activity during the last 10,000 years. As stated by Dr. Simkin in the Preface, the book is "the first chronologic summary of global volcanism published in English, the first comprehensive one-volume regional directory in English in over a hundred years, and the first cross-referenced Gazetteer of volcano names ever attempted." The book fully lives up to its billing. Perhaps more important, a computer data file, from which the book was drawn, now exists for use by scientists of all disciplines who have, or should have, an interest in volcanoes. Obviously, this volume will be an invaluable reference for volcanologists, but the authors hope that other specialists—in the social as well as physical sciences—will consider the information in the book in designing and conducting studies on the impacts of volcanism on man and the environment.

Volcanoes of the World is an up-to-date inventory of the 1,343 volcanoes that have been active in the past 10,000 years (Holocene period of geologic time). The core of the book, about 200 pages of computer printout, gives the main statistics of the 5,564 known Holocene eruptions. Prefaced by a 30-page Introduction, the data are arranged in four sections—Directory of Volcanoes, Chronology of Eruptions, Gazetteer, and Bibliography.

Whereas the computer-generated data summaries are of direct use to volcanologists, the Introduction is instructive for nonspecialists who have a general interest in volcanoes. In addition to explaining the preparation and use of the data summaries, the authors provide some historical and human perspectives on the reporting of volcanic eruptions. For example, they point out that the number of active volcanoes reported throughout history correlates with exponential population growth and other societal factors. Reports of eruptions increase with epochs of explorations and newsworthy eruptions [for example, Krakatau (1883), Mount Pelée (1902), and Mount St. Helens (1980)] and decrease with world wars or economic crises. The authors also caution that the historic record is incomplete, as the bulk of the Earth's volcanism principally takes place along the submarine segments of the spreading rift systems and, hence, is rarely detected or reported. Perhaps most important from a vantage point of volcanic hazards, Dr. Simkin and his associates remind us that "a volcano's long repose is more likely to be a cause for concern than reassurance..." because the historic record shows that the most explosive volcanoes, and most dangerous in terms of damage and fatalities, have been those that have had long periods of dormancy prior to their destructive eruptions.

In summary, *Volcanoes of the World* provides a long-overdue systematic inventory of global volcanism during the Holocene, especially welcome at a time when the tragic consequences of the paroxysmal May 18, 1980, eruption of Mount St. Helens are still fresh on the minds of the public and governmental institutions concerned with mitigation of volcanic hazards.

Robert I. Tilling

Publications

General Publications

Earthquakes and Young Volcanoes. By C. Dean Rinehart and Ward C. Smith. Edited by Genny Smith. Two-color; illustrated with maps, diagrams, and 30 photographs. 1982. William Kaufmann, Inc., One First Street, Los Altos, California 94022. 64 p. Paper only, \$5.95.

Earthquake. By Bryce Walker and the Editors of Time-Life Books. One volume in the Planet Earth series. Available from Time-Life Books, 541 North Fairbanks, Chicago, IL 60611. 1982. 176 pp. \$9.95 plus \$2.03 shipping cost.

This well-researched description of earthquakes and their dynamics is supplemented by spectacular photographs—both contemporary and antique—and excellent illustrations. Six chapters discuss historical occurrences, seismology, earthquake prediction, associated hazards such as tsunamis, and Japan's great risk and considerable preparations. Additional essays discuss such topics as plate tectonics, California's clear and present danger, and San Francisco's day of wrath. A thorough bibliography indicates directions for further reading. Other entries in this series will cover the atmosphere and the oceans.

Coping with Stress Following a Natural Disaster: The Volcanic Eruption of Mt. St. Helens. By Shirley A. Murphy. Ph.D. thesis, University of Oregon, Psychiatric-Mental Health Department, School of Nursing, Portland, OR 97201, (503) 225-7827. 1981. 212 p. For availability, contact Ms. Murphy at the above address or a branch of the Inter-Library Loan system.

The thesis addresses stress as it is related to (1) the presumed or confirmed death of a close relative or friend, (2) the loss of a permanent or recreational residence, (3) the efficacy of self-help and social supports in mitigating adverse health effects when coping with loss, and (4) the media's portrayal of loss following a disaster. Suggested clinical interventions include the identification of high-risk individuals and precrisis training of professionals.

The New Madrid Earthquakes. By James Lal Penick, Jr. 1981. Revised edition. Columbia: University of Missouri Press. 176 p. \$7.95.

Drawing from many historical sources, the author describes the great New Madrid earthquakes and their impacts upon the settlers of the central Mississippi River Valley. Although tremors are regularly detected by instruments in the region, a false sense of security is felt by many of the 12 million people who now inhabit the area which suffered damage in 1811 and 1812. Attitudes among disaster planning officials in the Mississippi Valley may be challenged by this well-written narrative. The revised edition examines recent scientific thought about the origin of these earthquakes and reflects a renewed public interest in the hazards associated with the area.

Assessing the Seismic Vulnerability of Different Types of Existing Housing Structures. Daniel L. Schodek. Department of Architecture, Graduate School of Design, Harvard University, 48 Quincy Street, Cambridge, MA 02138, (617) 495-2591. 1981. 6 p. Available from the author.

The paper describes a method for estimating the overall seismic vulnerability of an urban area and for pinpointing groups of structures particularly susceptible to earthquake damage. The method utilizes a computer-based cartographic data system and consists of the following steps: (1) development of data bases through analyses of aerial photographs as well as census tracks and tax records, (2) housing-type identification through photogrammetric techniques and a knowledge of housing forms prevalent in the area, (3) mapped distribution of housing types, (4) analysis of construction types and damage patterns to which each is prone, and (5) seismic vulnerability analysis through architectural and engineering assessment procedures. The method can be used for disaster planning and for identifying policy responses for implementation during rehabilitation periods.

The Solution of the Inverse Problem in Geophysical Interpretation. Edited by R. Cassinis. 1982. *Physical Sciences*, volume 11. Ettore Majorana International Science Series. Plenum Publishing Corporation, New York, NY. 381 p. \$45.00.

Large Earthquakes in New Zealand: Anticipation, Precaution, Reconstruction. The Royal Society of New Zealand (RSNZ) Miscellaneous Series 5. 1981. 208 p. Available from RSNZ, Box 12-249, Wellington, New Zealand. NZ\$30.00.

The book includes 30 papers presented at the Conference on Large Earthquakes which was held at Napier, New Zealand, from January 31–February 3, 1981, 50 years after the 1931 Hawkes Bay earthquake. This area of New Zealand was devastated not only by a severe earthquake shock, but also by consequent disasters—uncontrollable fires, rescue and communication problems, and difficulties in organizing aid and supply operations immediately and in the following weeks. Administrative, financial, and social problems which were created by the disaster remained for years. The papers in this book show preparedness for and various responses to an earthquake of similar magnitude, if it were to occur today.

The 30 papers will be of value to those concerned with civil defense, fire, and police services; town planning authorities and members of local and national government bodies; insurance and building industry representatives; social scientists and earth scientists; and to all people living in areas potentially subject to earthquake activity.

The book includes the following articles:

The reduction of earthquake hazards by J. L. Roberts.

"... the gates of Stress and Strain ..." by R. L. Walcott.

The vast event—How vast and how often? A statistical perspective of earthquake occurrence by W. D. Smith.

Synoptic earthquake forecasting as a basis for disaster prevention by F. F. Evison and D. A. Rhoades.

The effect of earthquake prediction on civil defense by R. H. F. Holloway.

Earth deformation and major earthquakes by G. J. Lensen.

Earthquake-induced geological hazards in urban areas by L. E. Oborn.

Social response to earthquake threat—An identification of the major themes in the research literature by A. R. Parr.

The science and politics of earthquake prediction by R. M. Hamilton.

Urban design and physical planning as tools to

make cities safer in earthquake-prone areas by A. Ciborowski.

Appropriate distribution of resources of optimum risk reduction by D. G. Eims, J. B. Berrill, and D. J. Darwin.

Survivability of structures in extreme magnitude earthquakes by D. J. Dowrick.

Dealing with the problem of earthquake-risk buildings: The Wellington City Council approach by K. S. Mulholland.

Geodetic surveys for earth deformation by A. J. Bevin.

A city engineer's problems in implementing countermeasures by P. Scoular.

New Zealand houses in earthquakes—What will happen? by R. C. Cooney and A. H. R. Fowkes.

Water supply operations and earthquake preparedness by H. Bayly and L. D. Smith.

The response of cylindrical liquid storage tanks to earthquakes by T. A. Moore.

Earthquakes engineering research at the Physics and Engineering Laboratory, DSIR, by R. G. Tyler and J. L. Beck.

Large-scale disasters—Planning for an effective initial response by R. T. Jones.

Civil defence response to a major earthquake by R. H. F. Holloway.

Information flow: Civil defence lifeblood by J. M. Flavell.

Police preparations for response to a large earthquake by W. Nicholl.

Fire service operations in the immediate post-earthquake phase by J. F. Wood.

Earthquake and the role of the fire service by R. G. Sampson.

Preparedness plan for building structural inspection following disaster by R. B. Shephard.

The building industry's ability to respond to an earthquake disaster by J. C. Mackersey.

The settlement of insurance claims following a large earthquake by J. E. Sherburd.

What have New Zealanders learned from earthquake disasters in their country by N. R. Britton.

Some behavioural aspects of response to natural disasters by G. E. Kearney.

Principles and Applications of Microearthquake Networks. By W. H. K. Lee and S. W. Stewart. 1981. Supplement 2 of *Advances in Geophysics*. 296 p. Academic Press, New York. \$32.00.

This volume reviews the fundamentals of micro-earthquake networks—instrumentation systems, data-processing procedures, methods of data analysis, and examples of applications. It includes a considerable amount of practical information pertinent to earthquake seismology. Two chapters discuss seismic-ray tracing, generalized inversion, and nonlinear optimization. The basic techniques of microearthquake data analysis are developed systematically. The book features an excellent bibliography and extensive tabulated data listing worldwide microearthquake networks and micro-earthquake surveys on land and at sea. Other useful features are a glossary of abbreviations and unusual terms and author and subject indexes.

Dynamics of Structures, A Primer. By Anil K. Chopra. 1981. Published by the Earthquake Engineering Research Institute (EERI), 2620 Telegraph Avenue, Berkeley, CA 94704 (with support from the National Science Foundation). \$7.00 plus handling charge. 126 p. Order from the Institute at the above address.

The book provides the nonspecialist in dynamics of structures with the basic concepts and knowledge needed to understand the response of structures excited by ground shaking. It is intended to be an introduction for the reader who is interested only in the fundamentals of the dynamics of these structures and not in a formal detailed treatment and comprehensive coverage of the subject. The monograph is divided into three sections: Dynamics of Simple Structures, Dynamics of Multistory Buildings, and Dynamic Analysis and Building Code Procedures.

The Chopra monograph is the second in a series on different aspects of earthquake engineering which is being published by EERI with support of the National Science Foundation. The first monograph in the series is *Reading and Interpreting Strong Motion Accelerograms* by D. E. Hudson, California Institute of Technology. The Hudson monograph provides the nonspecialist in strong-motion earthquake instrumentation and data processing with the basic knowledge needed to appreciate the information contained in typical accelerograms.

Abstract Journal in Earthquake Engineering. Volume 10: 1980 Literature. December 1981. National Information Service for Earthquake Engineering, Earthquake Engineering Research Center.

Volume 10 offers a comprehensive survey of world literature published in the field of earthquake hazards mitigation. It includes 1850 abstracts and citations of technical papers, reports, books, codes, and conference proceedings. The abstracts have been drawn from the *Proceedings of the Seventh World Conference on Earthquake Engineering* and from 96 technical journals and the publications of academic, professional, and governmental organizations in 24 countries. Subject and author indexes provide easy access to items of interest. Listed below are the journal topics:

General Topics and Conference Proceedings
Selected Topics in Seismology
Engineering Seismology
Strong Motion Seismometry
Dynamics of Soils, Rocks and Foundations
Dynamics of Structures
Earthquake-Resistant Design and Construction
and Hazard Reduction
Earthquake Effects
Earthquakes as Natural Disasters

For more information contact:
Abstract Journal in Earthquake Engineering,
Earthquake Engineering Research Center,
47th Street and Hoffman Boulevard,
Richmond, California 94804

Earthquakes and Underground Pipelines: An Overview. By Ivan Nelson and Melvin L. Baron. Grant Report No. 17. Weidlinger Associates, Consulting Engineers, 110 East 59th Street, New York, NY 10022, (202) 838-2830. 1981. 48 p.

This technical report summarizes the results of a 3-year research program on underground water lifelines that was done for the National Science Foundation. Earthquake motion affecting lifelines, seismic risk analysis, and the computed responses of pipelines to earthquake motion are described. In addition to examining recent research conducted under artificially induced loads, the report discusses the design of measuring apparatus for equipment subjected to actual earthquake stresses.

Earthquake Interpretations: A Manual for Reading Seismograms. By Ruth B. Simon. 1981. 150 p. \$9.95. Available from William Kaufmann, Inc., One First Street, Los Altos, CA 94022.

From the publisher's preface:

Earthquake Interpretations is designed for students of seismology and geophysics and for others—technicians, researchers, and planners—who work with earthquake records. It provides a more comprehensive treatment than most other books on seismology. Included here are reproductions and interpretations of dozens of actual earthquake records, arranged by increasing distance from the recording stations, at differing depths and directions, and recorded on different types of seismographs.

The seismograms themselves are both technically interesting and intelligible. Each earthquake record has been chosen to illustrate significant points which might be passed over the casual or inexperienced observer. Clear instructions for the beginning interpreter make the progressions easy to follow.

This manual is of continuing value to many kinds of readers. Earth scientists in research institutions, government, and industry will find it helpful with instrumentation, data processing, and other geophysical methods of studying the Earth. And earth science instructors and students will find it an important tool for helping discover clues to the internal structure of the Earth and its ever-changing activities.

Volcanic Hazards Workshop. California Department of Conservation's Division of Mines and Geology, California Office of Emergency Services.

The status of volcanic prediction and emergency-response capabilities in hazard zones of California was reviewed at the workshop in Sacramento on December 3-4, 1981. The workshop defined areas of risk, appraised methods of forecasting eruptions, and examined planning needs in the light of experience at Mount St. Helens. The proceedings will be made available through Marti Johnson, Division of Mines and Geology, Room 1341, 1416 9th Street, Sacramento, CA 95814, (916) 445-1825.

United Nations Publications

(UNDRO—Office of the United Nations Disaster Relief, Palais des Nations, 1211 Geneva 10, Switzerland)

Disaster Prevention and Mitigation: A Compendium of Current Knowledge, English/French/Spanish

- Volume 1: Volcanological Aspects—\$6
- Volume 2: Hydrological Aspects—\$3
- Volume 3: Seismological Aspects—\$10
- Volume 4: Meteorological Aspects—\$8
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- Volume 6: Building and Civil Engineering Aspects (June 81)
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Undro News

Newsletter published every two months (bilingual English/French)

Case Reports

- Turkey, Earthquake, Van Province, 1976. (No. 003) English.
- Mozambique, Floods, 1977. (No. 004) English/French.
- Oman, Cyclone and Torrential Rains, 1977. (No. 005) English.
- Sri Lanka, Cyclone, 1978. (No. 006) English.
- Jamaica, Floods, 1979. (No. 007) English.
- Dominica, Hurricane, 1979. (No. 008) English.
- Dominican Republic, Hurricanes, 1979. (No. 009) English.

USGS Publications

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- T Public Inquiries Office, Rm. 1C45, Federal Bldg., 1100 Commerce St., Dallas, TX 75242.
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(Editor's note: Because of the large number of open-file reports and the restricted space in the Earthquake Information Bulletin, every seismological report published will no longer be listed. Full details on all Survey publications are given in *New Publications of the Geological Survey*, which appears each month and is available from the US Geological Survey, 582 National Center, Reston, VA 22092.)

OF 81-0037. A seismicity and seismotectonic study of the Kermit seismic zone, Texas. By G. R. Keller, A. M. Rogers, and R. J. Lund. 388 p. (NC, Da, M, T; Texas Bur. Econ. Geology, Univ. of Texas at Austin, Univ. Station, Box X, Austin, TX 78712.) Microfiche \$3.50; paper copy \$50.25.

OF 81-0050. Development of techniques for evaluating seismic hazards of creeping landslides and old dams. By R. E. Goodman. 76 p., 1 over-size sheet. (NC, Da, M.) Microfiche \$3.50; paper copy \$10.

OF 81-0093. Induced seismicity and earthquake prediction studies in South Carolina. By Pradeep Talwani, B. K. Rastogi, and Don Stevenson. 221 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$28.50.

OF 81-0117. Seismicity near Albuquerque, New Mexico, 1976-1978. By L. H. Jaksha and Jerry Locke. 18 p. (NC, Da, M, U, LA, T; USGS, Seventh Floor, 505 Marquette, NW. (P.O. Box 26659), Albuquerque, NM 87125.) Microfiche \$3.50; paper copy \$2.25.

OF 81-0271. Surface fault traces and historical earthquake effects near Los Alamos Valley, Santa Barbara County, California. By P. D. Gupta, E. G. Heath, and G. E. Brogan. 148 p., 14 over-size sheets. (NC, Da, M.) Microfiche \$10.50; paper copy \$50.25. (Contract report)

OF 81-0277. Mechanisms of fracture and friction of crustal rock in simulated geologic environments. By B. K. Atkinson, N. J. Price, S. M. Dennis, P. G. Meredith, D. MacDonald, and R. F. Holloway. 158 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$20.50.

OF 81-0278. Investigation of radon and helium as possible fluid-phase precursors to earthquakes. By H. Craig, Y. Chung, J. E. Lupton, S. Damasceno, and R. Poreda. 103 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$13.25.

OF 81-0290. Earthquake research and network operations in the intermountain seismic belt—Wasatch Front. By R. B. Smith and W. J. Arabast. 331 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$43.

OF 81-0354. Kilauea Volcano, Hawaii: Chronology and morphology of the surficial lava flows. By R. T. Holcomb. 335 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$54.75.

OF 81-0356. Regenerate faults of small Cenozoic offset: Probable earthquake sources in the Southeastern United States. By C. M. Wentworth and Marcia Mergner-Keefer. 37 p., 1 oversize sheet. (NC, Da, M; South Carolina Geol. Survey, State Devel. Board, Harbison Forest Rd., Columbia, SC 29210.) Microfiche \$4; paper copy \$4.75.

OF 81-0380. Geologic studies in an area of induced siesmicity at Monticello Reservoir, South Carolina. By D. T. Secor, Jr. 42 p., 9 oversize sheets, scale 1:24,000 (1 inch = 2,000 feet). (NC, Da, M.) Microfiche \$8; paper copy \$21.50.

OF 81-0381. Seismic damage assessment for high-rise buildings. By R. E. Scholl. 263 p. (NC, Da, M.) Microfiche \$350; paper copy \$34.

OF 81-0384. A field study of earthquake prediction methods in the central Aleutian Islands. By C. Kistlinger, S. Billington, R. Bowman, J. C. Harrison, S. Ihnen, C. Meertens, J. Pohlman, K. Sougstad, and S. T. Morrissey. 54 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$7.

OF 81-0450. Study of earthquake recurrence intervals on the Wasatch fault, Utah. By F. H. Swan III, K. L. Hanson, D. P. Schwartz, and P. L. Knapfer. 49 p., 6 oversize sheets. (NC, Da, M.) Microfiche \$6.50; paper copy \$7.75. (Contract report)

OF 81-0454. 1980 annual of current earthquake literature. By B. S. Hayashida, M. L. Kauffman, and W. H. K. Lee. 386 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$50.

OF 81-0482. Catalog of earthquakes along the San Andreas fault system in central California, July-September 1977. By S. M. Marks and L. Fluty. 43 p. (NC, Da, M, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 90012.) Microfiche \$3.50; paper copy \$5.50.

OF 81-0523. Dry tilt: A ground deformation monitor as applied to the active volcanoes of Hawaii. By K. M. Yamashita. 22 p. (NC, Da, M; USGS Library Hawaii Volcano Observatory, HI 96718.) Microfiche \$3.50; paper copy \$2.75.

OF 81-0564. The Geothermal Research Program of the U.S. Geological Survey. By W. A. Duffield and Marianne Guffanti. 113 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$14.50.

OF 81-0572. Bibliography on landslides, soil liquefaction, and related ground failures in selected historic earthquakes. By D. K. Keefer and N. E. Tannaci. 39 p. (NC, Da, M, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$3.50; paper copy \$5.

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OF 81-0686. Network-Day Tape software users guide. By Madeline Zirbes and Ray Buland. 215 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$27.75.

OF 81-0736. Review of earthquake activity and current status of seismic monitoring in the region of the Bradley Lake hydroelectric project, southern Kenai Peninsula, Alaska. By J. C. Lahr and C. D. Stephens. 34 p. (NC, Da, M, A, S, SF, LA; USGS, Room 207, O'Neill Bldg., Univ. Alaska (P.O. Box 80586), Fairbanks, AK 99708; Alaska Div. Geol. and Geophys. Surveys, 3001 Porcupine Dr., Anchorage, AK 99501; and University Ave. (P.O. Box 80007), Fairbanks, AK 99708.) Microfiche \$3.50; paper copy \$4.25.

OF 81-0977. Lineaments and faults of Wisconsin, Minnesota, and the western part of the northern peninsula of Michigan. By S. I. Dutch. 29 p., 4 oversize sheets, scale 1:2,500,000 (1 inch = about 40 miles) and scale 1:1,000,000 (1 inch = about 16 miles). (NC, Da, M.) Microfiche \$5.50; paper copy \$10.

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OF 81-1149. Strong-motion data from the Westmorland, California, earthquake of April 26, 1981. By R. P. Maley and E. C. Etheredge. 20 p. (NC, Da, M, SF, LA; California Div. Mines and Geol., Room

1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$3.50; paper copy \$2.50.

OF 81-1150. *The Soviet-American exchange in earthquake prediction*. Edited by Henry Spall and D. W. Simpson. 539 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$70. (Thirteen of the 21 reports in this collection have been published elsewhere.)

OF 81-1173. *Geologic map along a kilometer segment of the San Andreas fault zone, southern Diablo Range, California*. By M. J. Rymer. 2 over-size sheets, scale 1:12,000 (1 inch = 1,000 feet). (NC, Da, M, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$1; paper copy \$5.25.

OF 81-1214. *Processed accelerogram from Monticello Dam, Jenkinsville, South Carolina, 18 October 1979, 0705 UTC*. By P. N. Mork and A. G. Brady. 21 p. (NC, Da, M; South Carolina Geol. Survey, Harbison Forest Rd., Columbia, SC 29210.) Microfiche \$3.50; paper copy \$2.50.

OF 81-1325. *Catalog of earthquakes along the San Andreas fault system in central California, October-December 1977*. By L. Fluty and S. M. Marks. 48 p. (NC, Da, M, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$3.50; paper copy \$6.

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OF 82-0208. *New York Bight fault*. By D. R. Hutchinson and J. A. Grow. 21 p. (NC, Da, M; USGS, Quissett Campus, Woods Hole, MA 02543.) Microfiche \$3.50; paper copy \$2.50.

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OF 82-0282. *Surface displacement on the Imperial and Superstition Hills faults triggered by the Westmorland, California, earthquake of 26 April 1981*. By R. V. Sharp, J. J. Lienkaemper, and M. J. Rymer. 38 p. (NC, Da, M, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$3.50; paper copy \$4.75.

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Eruption of Cerro Negro Volcano, west-central Nicaragua, November 1968. The black cloud contains volcanic "bombs" that were hurled hundreds of feet into the air; as many of these rolled down the slopes of the volcano, they produced the streaks that radiate from the crest. The chain of active and dormant volcanoes in Central America resembles the Cascade volcanoes of the Pacific Northwest.

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UNITED STATES
DEPARTMENT
OF THE
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GEOLOGICAL
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**UNITED STATES DEPARTMENT OF THE
INTERIOR**

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GEOLOGICAL SURVEY

Dallas L. Peck, Director

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Waverly J. Person
- 119 **Publications**

Cover: Remains of a building at Francisco León, a village 3 miles south of El Chichón Volcano in southeastern Mexico. The village was destroyed by pyroclastic flows on April 3-4, 1982. The bent reinforcement rods show the force of the blast as well as the direction of flow. (Photograph by Robert I. Tilling.)

Volcanic Hazard Alert Issued for Long Valley- Mono Lake Area of California

Deep-seated magma near Yosemite shows signs of movement that have researchers wondering if an eruption is imminent.

The ski resort of Mammoth Lakes, nestled against the east front of the Sierra Nevada just east of Yosemite National Park, knows about natural hazards. It is still being shaken by an unusual sequence of earthquakes that started in 1978 and included four earthquakes of magnitude 6 within 48 hours of each other in May 1980. An earthquake hazard watch is still in effect.

Now the U.S. Geological Survey has issued a notice of potential volcanic hazard for the area that warns that "the outbreak of volcanic activity is a possibility but by no means a certainty." Nothing may happen, but the possible hazards being discussed range from moderate steam explosions to a cataclysm that could dump more than 6 inches of ash downwind as far east as Salt Lake City.

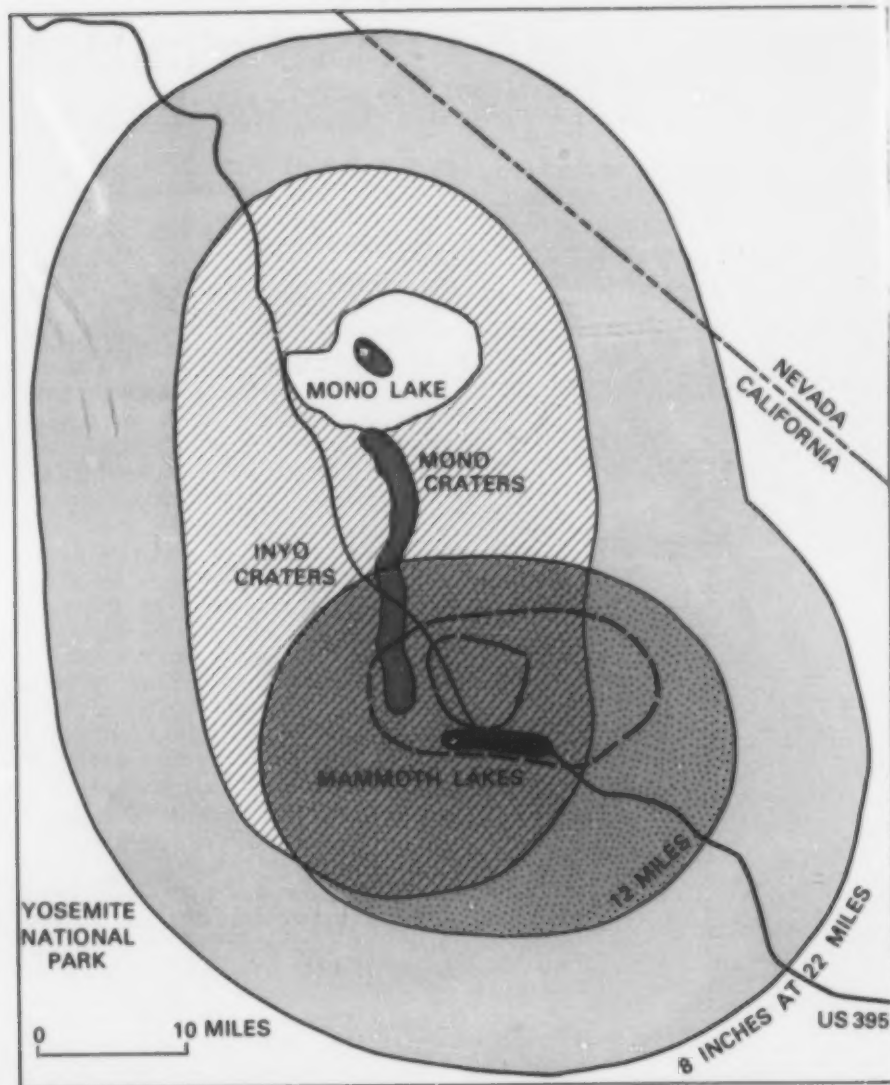
"It was only [in early May] that it dawned on us just what might be happening," says Roy Bailey of the U.S. Geological Survey in Reston, Virginia. Bailey is coordinator of the U.S. Geological Survey's volcanic program. "We had been treating it strictly as an earthquake hazard. There's really good evidence now that there's magma moving around at depth and it could reach the surface." If it did, the result would be an eruption.

The realization that there is a potential volcanic hazard came at an unrelated Department of Energy meeting in early May that was called to discuss a possible deep-drilling project in the Mono Craters

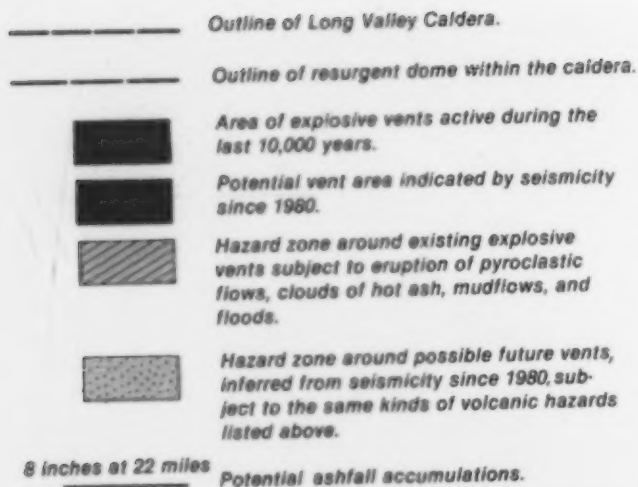
Mono Craters looking south with Mono Lake in the lower left and the Sierra Nevada in the distance. Note the crescent shape of the craters which may indicate the development of another caldera like the Long Valley Caldera. (Photograph by Roland Van Huene.) ►





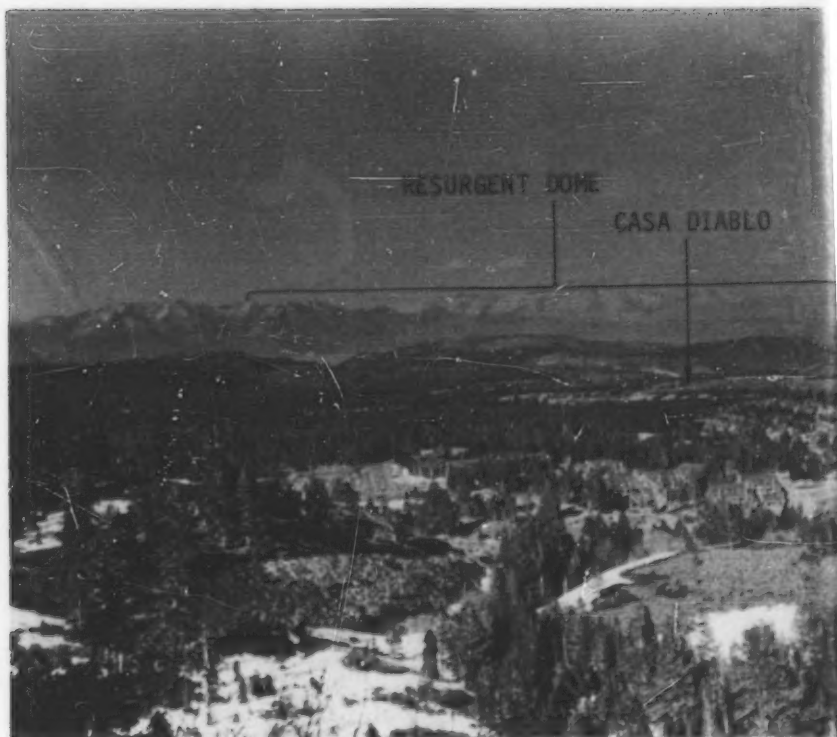


U.S. Geological Survey scientists have defined some preliminary volcanic hazard zones in east-central California.



area. Mammoth Lakes, just to the south, was simply a convenient place to meet. The volcanologists present, some of whom had come from the Survey's Cascades Volcanic Observatory near Mount St. Helens, took particular interest in a talk by Alan Ryall, a seismologist from the University of Nevada. Most of Ryall's listeners, including Bailey, were hearing for the first time that intense swarms of earthquakes, accompanied by spasmodic tremors, had not been scattered broadly over the area since their appearance in 1980, as most had assumed. Instead, the earthquakes and the tremors were concentrated at a site a few miles from the meeting room. (Volcanologists generally consider spasmodic tremor to be the result of rock fracturing associated with the movement of magma or magmatic gases.)

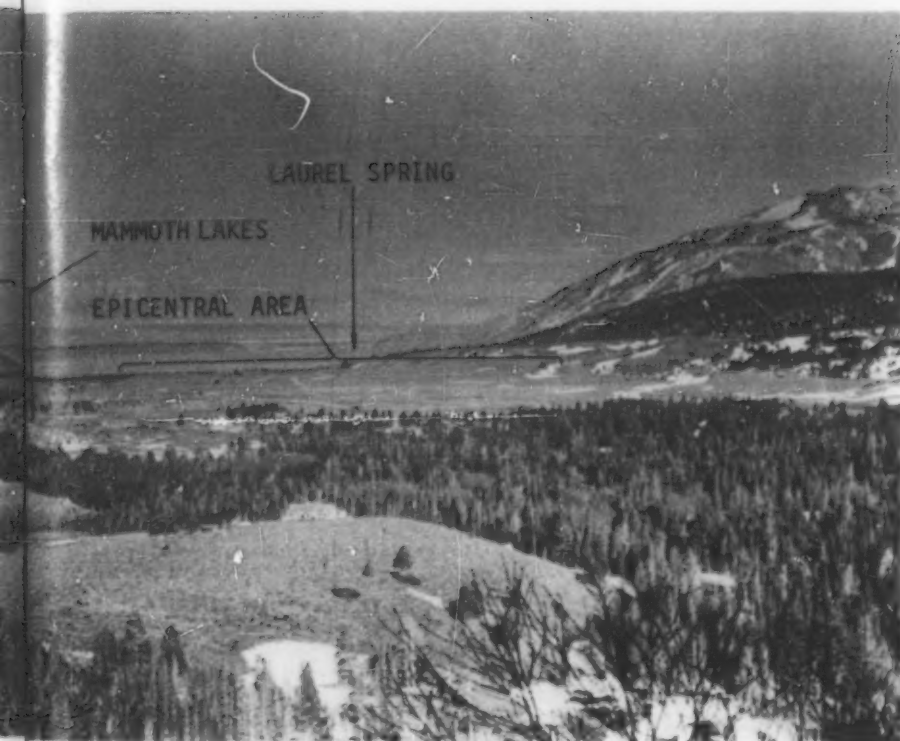
Ryall's listeners became even more attentive when they learned that the earthquakes at the nearby site had risen from a depth of about 5 miles in 1980 to about 3 miles in July 1981, when a particularly strong swarm hit. "That got us excited," Bailey recalls. At the time of the July quakes, Ryall and his colleagues were a bit concerned that the tremor was so intense, but the episode ended with no apparent after-effect. Consequently, they did not determine the depth of the earthquakes until the data came up for analysis some months later. After listening to the seismic rumblings



View of the southern margin of the Long Valley Caldera showing the location of Mammoth Lakes, the Casa Diablo fumarole area, the epicentral area of the 1980-82 seismic activity, and the resurgent dome of the caldera. (Photograph by Tom Casadevall, Cascades Volcano Observatory, Washington, May 4, 1982.)

of Mount St. Helens for 2 years, the volcanologists could not take the data quite so matter-of-factly.

The excitement was not over. A few volcanologists remaining after the meeting felt a series of small earthquakes shake the Mammoth Lakes area. Ryall had returned to Nevada by then, but he called to pass on the latest observations—the earthquakes, and supposedly the magma, had ascended to within a mile or so of the surface. “That really got us excited,” Bailey says. A second call to say that a better depth estimate was 2.5 miles did little to calm the group. Something should be done, the volcanologists agreed.



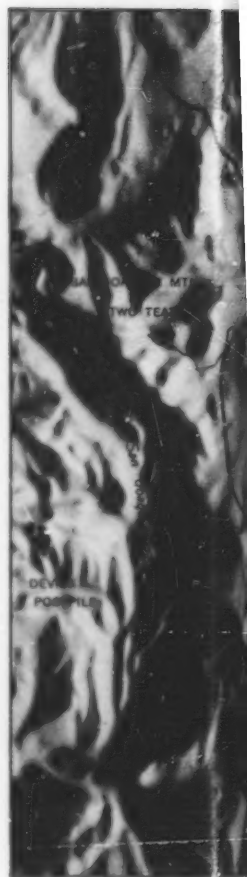
The result of these revelations was the issuance on May 26 by the Geological Survey of a notice of potential volcanic hazard, the lowest of three levels of official concern. In addition to the localized ascending spasmodic tremor, it noted other evidence suggesting that magma could be moving toward the surface. Seismic studies in 1976 by Don Steeples and H. M. Iyer of the U.S. Geological Survey in Menlo Park, California, and in 1980 by Alan Ryall and Floriana Ryall of the University of Nevada had detected a magma chamber near Mammoth Lakes. It is 6 miles across and extends from a depth of 5 miles to 9 miles or more, according to Bailey. It appears to be the residuum of a magma body that rose near the surface 700,000 years ago and released about 150 cubic miles of ash. (Mount St. Helens probably did not manage one-quarter of a cubic mile.)

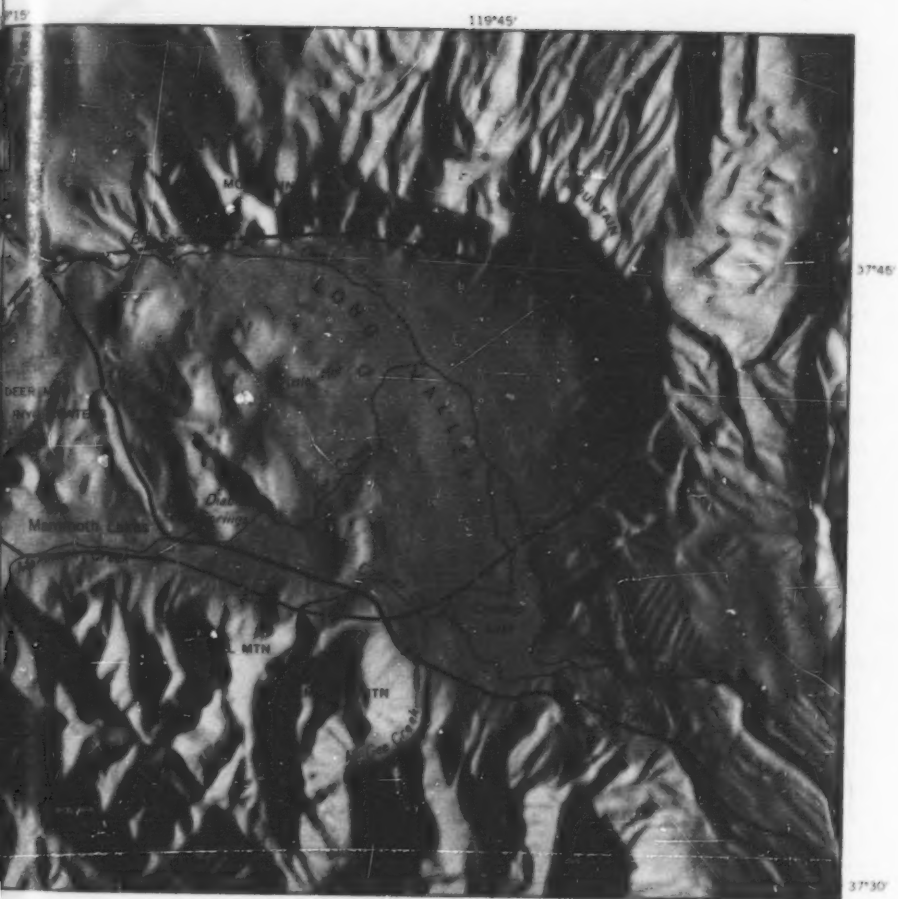
The expulsion of that much ash caused the magma chamber roof to collapse, forming the Long Valley Caldera. The caldera is a 20- by 10-mile elliptical depression that includes, near its southwest edge, both the town of Mammoth Lakes and the site of the spasmodic tremors. The chamber has regularly leaked magma in eruptions about every 200,000 years. However, the next major volcanic activity would not be expected for another 100,000 years, if the pattern were to hold.

Recently, researchers decided that the magma chamber might not be as quiet as had been thought. In October 1980, a precise releveling survey across part of the caldera, prompted by the May 1980 earthquakes, found a bulge in the ground over the magma chamber that is 10 inches high and 18 miles wide. James Savage and Malcolm Clark of the U.S. Geological Survey in Menlo Park believe that about 0.04 cubic mile of magma entered the chamber sometime between July 1979 and October 1980 and raised the bulge.

Whether the stress resulting from the magma injection triggered the four earthquakes of May 1980 or the earthquakes induced the magma movement is unclear. In a similar situation on the Izu Peninsula near Tokyo, Japanese researchers found that uplifts over a magma chamber definitely precede nearby earthquakes. James Savage and Wayne Thatcher of the U.S. Geological Survey in Menlo Park have calculated that an expanding magma chamber at a depth of 7 miles would have produced the proper stresses to trigger the observed Japanese earthquakes. In any case, most researchers now assume that the appearance of spasmodic tremor in mid-1980 and the creation in January 1982 of new steam vents 2 miles east of the tremor site means that magma from some deep source began moving in the form of an ascending tongue.

Although the activity near Mammoth Lakes has now alerted volcanologists to the possibility of magma reaching the surface, they face unusually difficult problems in forecasting future developments, if any. At Mount St. Helens, they had a single main vent to watch and reasonably detailed studies of its past behavior to go by. The Mammoth Lakes region, on the other hand, has many vents from past eruptions and a complex volcanic history. In addition, the geologic record of volcanic activity in Long Valley Caldera is





Aerial view of the Long Valley Caldera showing the outline of the crater.

older and harder to read. None of the caldera eruptions appear to be less than 50,000 years old, which means that much of the geologic detail required to formulate hazard forecasts is likely to have been eroded away or buried by nonvolcanic material. The odds of a repetition of the ancient caldera-forming eruption are impossible to calculate; however, even after a pause of 700,000 years, the possibility cannot be excluded, says C. Dan Miller of the U.S. Geological Survey in Denver. At Yellowstone, for instance,

cataclysmic eruptions have created three overlapping calderas at intervals of 600,000 years, he notes.

To further complicate matters, volcanologists believe that another major magma body is making itself known in the area by forming a chain of highly active craters called the Mono and Inyo Craters. They form a chain that runs 18 miles in a north-south direction and juts into the far western end of the Long Valley Caldera. While it builds up internal gas pressures for its own caldera-forming eruption in the distant future, this deep chamber is erupting ash and lava every few hundred years. No one would be surprised if one of these craters near Mammoth Lakes erupted soon; some of the eruptions of the past 1,000 years have been within the caldera itself. The spasmodic tremors are about 3 miles to the southeast of the craters active in the past 10,000 years, which bothers volcanologists because the caldera seismic activity could conceivably reactivate the young volcanic area to the west.

In light of the obvious uncertainties, a U.S. Geological Survey report* on potential hazards discusses the full range of possibilities. Nothing may happen—the apparent tongue of magma might stop and freeze in place. Or the magma's heat, combined with ground water, might produce a phreatic eruption whose effects could extend 6 miles farther downwind. A moderate explosive eruption about the size of Mount St. Helens could send ash flows out to a distance of 12 miles and drop airborne ash 2 inches deep 50 miles downwind. Depending on the wind direction, that could be Yosemite Village, the edge of the Great Valley, or well into Nevada.

Another caldera-forming eruption, spewing ash from several hundred cubic miles of magma, could dump 3 feet or more of ash on a zone of "severe or total devastation" that would be 145 miles across, the Survey report says. Three hundred miles downwind (most likely western Utah), 7.5 inches of ash would cover the ground. Apparently, little ash from the caldera has ever reached the California coast.

Historically, smaller, less violent eruptions are

*Miller, C. Dan, Mullineaux, Donal R., Crandell, Dwight R., and Bailey, Roy A., 1982, *Potential Hazards from Future Volcanic Eruptions in the Long Valley-Mono Lake Area East-Central California and Southwest Nevada, a Preliminary Assessment*: Circular 877, 10 p. Free on application to Eastern Distribution Branch, U.S. Geological Survey, 604 South Pickett Street, Alexandria, VA 22304.

much more likely than cataclysmic ones. However, Mount St. Helens surpassed all of its known eruptions when it blew apart in 1980. With that in mind and their limited understanding of what is happening near Mammoth Lakes, volcanologists are taking the situation quite seriously.

Kerr, Richard A., copyright 1982, by the American Association for the Advancement of Science: *Science*, 1982, vol. 126, p. 1302-1303.

Further reading

Earthquake Information Bulletin, 1981, The Eastern Front of the Sierra Nevada—Prone to Earthquakes and Volcanic Eruption: Vol. 13, no. 6, p. 216-224.



◀ The fire in 1906 gutted the Palace Hotel, San Francisco.

▼ Street collapse on Union Street, San Francisco, that was caused by liquefaction during the 1906 earthquake.



Jack London and the San Francisco Earthquake

The following article is based on Experiences in the Earthquake and Fire by Jack London and Gertrude Atherton; found in San Francisco: 1906 & Before, Lewis Osborne, Ashland, 1973.

After it was over, it seemed to many, and especially to eyewitnesses like Jack London, that the earthquake and fire had devastated San Francisco. However, people were confident that, like the phoenix, San Francisco would rise from the ashes and regain her place as the "Imperial City of the West."

At 5:13 a.m. on Wednesday, April 18, 1906, the first shock hit San Francisco, and, almost immediately thereafter, the fire began.

"Within an hour after the earthquake shock the smoke of San Francisco's burning was a lurid tower visible a hundred miles away. And for three days and nights this lurid tower swayed in the sky, reddening the sun, darkening the day, and filling the land with smoke."

No area was safe from the flames. The fire spread rapidly because there was no organized response and no means of communication; all had been destroyed by the earthquake and the rapid spread of the fire. "All the shrewd contrivances and safeguards of man had been thrown out of gear by thirty seconds' twitching of the earth-crust."

By the afternoon, about one-half of the center of the city was gone. At this time, London watched the burning city from San Francisco Bay. As with great fires of this type, the heated air created an enormous updraft even though there were no winds. Consequently, the fire built its own tremendous funnel. "Day and night this dead calm continued, and yet, near to the flames, the wind was often half a gale, so mighty was the suck."

Jack London spent a fair amount of time walking through San Francisco the first night. At that time, the heart of the city was deserted, except for the policemen patrolling the streets and the watchmen guarding the empty buildings against looters. Yet, he knew these structures were doomed—the water supply was gone, the dynamite was nearly exhausted, and two fires were converging at right angles upon

the defenseless area. Early the next morning (about 1:00 a.m.), he walked through the same district. There was, as yet, no fire, but the policemen and the watchmen were gone, and a rain of ashes was falling. No firemen or dynamiters were on their way because the area had been abandoned completely. Six blocks down Kearny Street, the street was a "wall of flame."

Soon another fire broke out uptown, and this one joined the other two pressing down upon the center of the city. "Surrender was complete. There was no water. The sewers had long since been pumped dry. There was no dynamite." The last side of this box of fire in the center city had been destroyed earlier on Wednesday. Among the burned buildings found there were the *Examiner*, the *Call*, and the Palace and Grand Hotels. To give an example of how rapidly the fire could spread: At 8:00 p.m. Wednesday evening, Union Square was packed with refugees; by 1:30 a.m. Thursday morning, three sides of the Square were burning; and by 2:30 a.m., the fourth side was engulfed.

Despite the horror of the earthquake and fire, London remarked on the calmness and quiet of the people watching almost everything they owned being destroyed and then fleeing the onrushing flames carrying a few possessions with them. "Never, in all San Francisco's history, were her people so kind and courteous as on this [first] night of terror." But what was so heartbreaking was to see these people "flinging out upon the street clothing and treasures they had dragged for miles." Vast sums of money were offered to those who had horses and (or) carts; thousands of dollars were willingly spent so that belongings could be transported out of the holocaust. And always there were men with bayonets, urging the refugees to keep moving with their trunks and bundles; dawdling could mean death for those following.

"Thursday.

Day was trying to dawn through the smoke-pall. A sickly light was creeping over the face of things. Once only the sun broke through the smoke-pall, blood red, and showing a quarter its usual size. The smoke-pall itself, viewed from beneath, was a rose color that pulsed and fluttered with lavender shades. Then it turned to mauve and yellow and dun. There was no sun."

An hour after sunrise, London walked past City Hall. All that was left was the bare steel frame; the

force of the earthquake had shaken the stone off the dome. Market Street was littered with wreckage, including the pillars of City Hall which had shattered into crosswise sections. The only two buildings in this section of the city not smoldering were the Post Office and the Mint. Occasionally, people would be seen emerging from the smoking ruins. "It was like the meeting of the handful of survivors after the day of the end of the world."

The fire continued the rest of Thursday and into Friday night. Thursday night, the firefighters made their great stand at Van Ness Avenue, but not soon enough to save Russian Hill, Telegraph Hill, and three-quarters of a mile of wharves and docks. The homes of the second-generation "nabobs" were dynamited in a solid zone across the fire's path. Although flames were able to leap the zone and there were scattered fires on Friday, they could be beaten out with wet blankets and rugs. The worst was over.

London described San Francisco after the fire as "like the crater of a volcano, around which are camped tens of thousands of refugees." Other refugees went to the Presidio (20,000), to surrounding towns and cities (an unknown number), and to anywhere they wanted, thanks to the free fares of the railways (an estimated 100,000). Relief committees were set up almost immediately in San Francisco and in the surrounding areas. Relief poured in from all over the country to assure that there would be no famine. The Federal Government had the situation well in hand. And almost before the ashes were cooled, the bankers and businessmen were making plans for the rebuilding of the "Imperial City of the West."

Janet Somerville Sachs

Earthquakes and Risk in California

Seventy-five years ago on April 18, 1906, northern California was struck by the most devastating earthquake in United States history. This great earthquake, magnitude $8\frac{1}{4}$ on the Richter Scale, ruptured the northernmost 270 miles of the 700-mile-long San Andreas fault. The ground along the fault moved an average of more than 12 feet north of San Francisco and about 6 feet to the south. Buildings were damaged in a 50-mile-wide region extending for over 350 miles parallel to the fault break.

San Francisco suffered disastrous losses, primarily from the fire caused by the earthquake. The fire consumed much of the city and left 250,000 people homeless. Over 700 lives were lost as a result of the earthquake, and property damage exceeded \$500 million in 1906 dollars. Similar damage in dollar values for the 1970's would result in losses greater than \$2 billion.

In the years since the great 1906 earthquake, earth scientists have learned much about the causes of such periodic upheavals of the Earth's surface. Most major earthquakes occur at the boundaries of the several large plates of crust that sit on the Earth's surface like paving stones. These plates are in constant motion, overriding, plunging beneath, or simply slipping past one another. This is the case for the North American and Pacific plates which meet in California along the well-known San Andreas fault zone and move at an average of 1.5 to 2 inches per year. Measurements taken over a long period of time indicate that this movement is irregular and episodic; segments of the adjoining plates may remain immobile and locked together for years, only to break free in a great lurch that may result in an offset of several feet over a few seconds as the two plates resume their slide-slip movement.

The U.S. Geological Survey recently concluded that the probability of a catastrophic earthquake occurring in California during the next three decades exceeds one chance in two. Dollar losses in such an event likely would total tens of billions of dollars, and fatalities could be in the thousands.

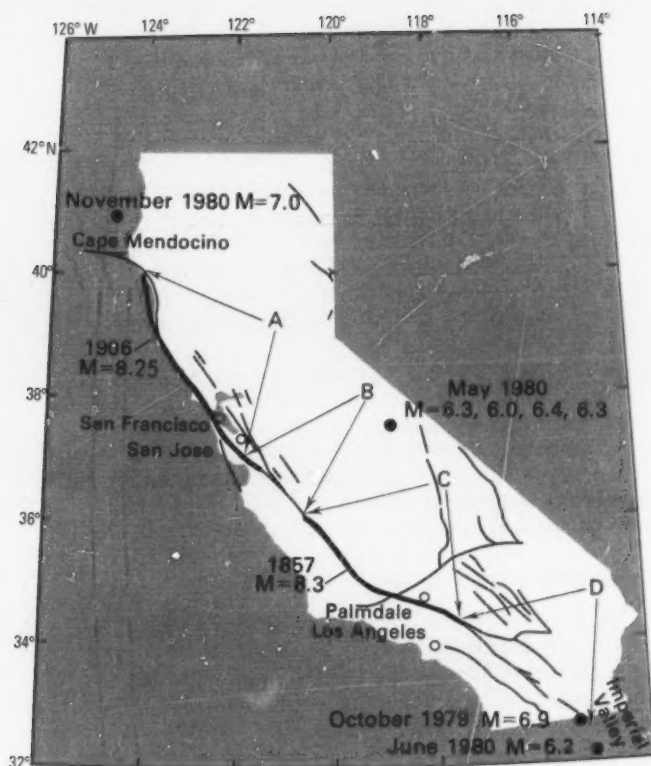


Figure 1.—Seven earthquakes of magnitude 6 or greater have occurred in or near California in the past 2 years, compared with only four in the previous 20 years. The extent of faulting caused by historic magnitude 8 earthquakes on the San Andreas fault is shown by heavy lines.

The Seismic Gap Theory

Analysis of the seismic activity of the major plate boundaries around the world has led to the recognition that ruptures along major plate boundaries tend to occur sequentially, affecting limited segments and often leaving intervening portions undisturbed as seismic gaps. With time, however, large earthquakes tend to occur in these seismic gaps before movement recurs on more recently ruptured segments. The locations and magnitudes of more than six major earthquakes have been forecast successfully by this theory since the mid-1960's.

Application of seismic gap theory to the San Andreas fault leads to the identification of four distinct fault segments: two that have ruptured in great earthquakes and two for which there is no historic record of any major earthquakes. These fault segments are shown in figure 1. From north to south, these segments are as follows:

- A. The northern 270 miles of the fault that ruptured in 1906.
- B. The central 100-mile-long segment that adjoins the 1906 break to the south.
- C. The 220-mile-long south-central segment that last ruptured in a magnitude 8.3 earthquake in 1857.
- D. The southernmost 120 miles of the fault that terminates at the birthplace of the fault in the Imperial Valley.

Estimates of the mean slip rate on each segment of the fault, when combined with detailed studies of ancient earthquakes preserved in the geologic record, give rather compatible estimates of long-term recurrence. When combined with the historic record of seismicity and measurements of crustal strain, they give us some estimate of today's short-term risk.

Probability of earthquakes on segment A

The recurrence of a magnitude 8 earthquake on the northern A segment (fig. 1) of the fault appears to be unlikely within the next several decades. Mean recurrence time, which is determined by dividing the fault displacement expected in a great earthquake by the long-term slip rate of the fault, implies an average return time of roughly 150 years for a 1906-sized event. Contemporary strain data also suggest that approximately another 50 to 100 years will elapse before the crust returns to its pre-1906 strain state, assuming that the current strain rate is maintained throughout the interval. Information pinpointing the time and size of previous major events is critically needed and would permit a significant refinement of these estimates.

If the sequence of events leading to the next great earthquake on the northern sectors of the San Andreas fault follows the same general pattern observed before 1906, then other lines of evidence would similarly suggest that a great earthquake is not imminent. In particular, the occurrence rate of earthquakes of magnitude 5 or greater was significantly higher during the 50-year period before 1906 than it has been since (fig. 2). In fact, no earthquakes as large as magnitude 5 occurred in the entire San Andreas

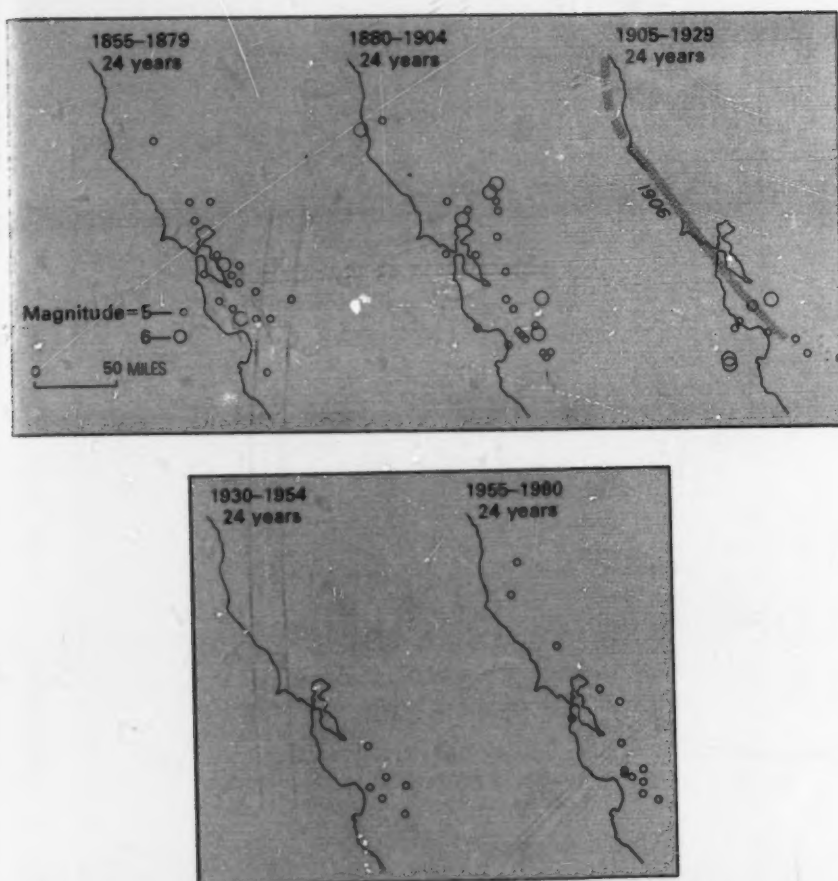


Figure 2.—Seismicity of the San Francisco Bay region from 1855 to 1980. Note the conspicuous decline in the number of earthquakes after 1906.

system to the north of San Jose in the first 50 years following the 1906 earthquake (fig. 3). Since about 1956, magnitude 5 earthquakes have begun to reappear within this northern coastal belt of faults, although the present level of activity appears to be well below the 19th century level. Repetition of the same general pattern of seismicity in advance of the next earthquake would imply that several decades characterized by increased frequency of damaging earthquakes should be expected. Similar long-term variations in the earthquake rate have been identified elsewhere in the world, notably in the focal regions of great earthquakes in Japan and in Kamchatka, U.S.S.R.

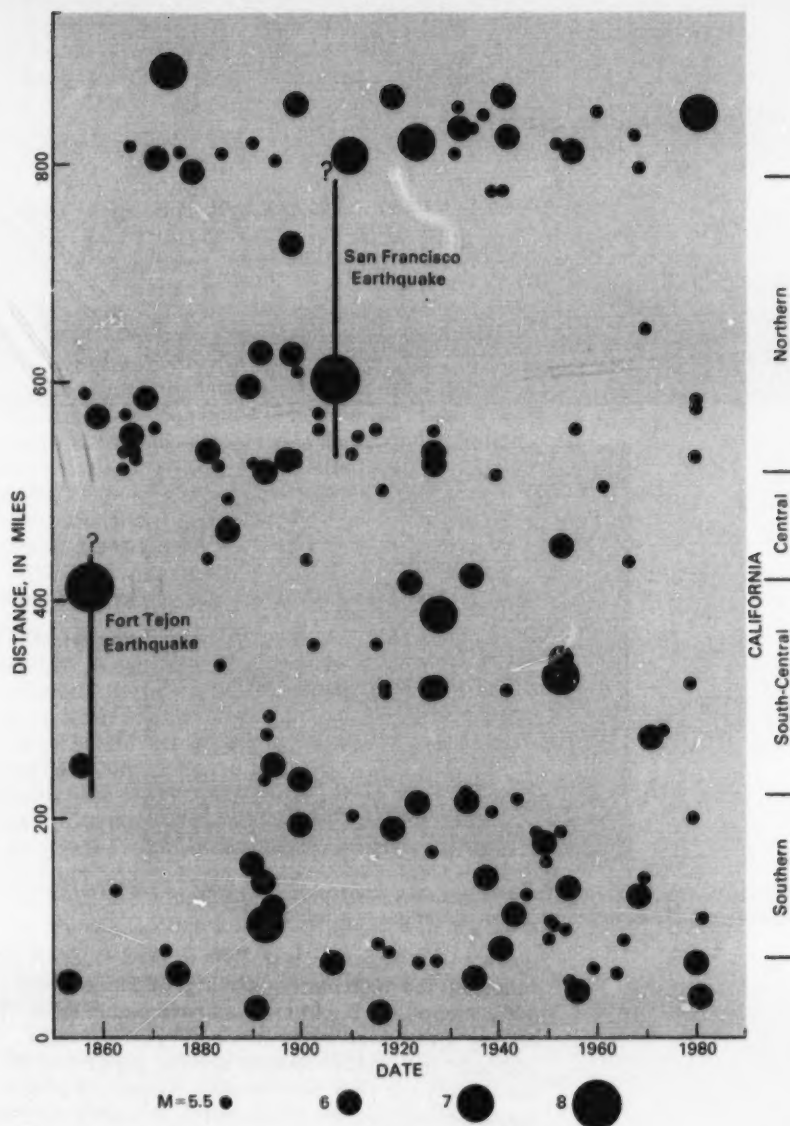


Figure 3.—Seismicity on the San Andreas fault system from 1850 to the present as a function of time and distance from the southern end of the fault. Extent of surface faulting in the 1857 to 1906 earthquakes is shown by vertical lines.

A significant aspect of this seismic cycle model, as applied to northern coastal California, is that it forecasts that the region will experience magnitude 6 to 7 earthquakes at a frequency comparable to that of the 19th century, or about one per decade, for several decades to perhaps a century before the next great earthquake of magnitude 8 or greater occurs.

Such a series of magnitude 6 to 7 earthquakes locally may pose as serious a hazard as a great earthquake on the San Andreas fault.

Probability of earthquakes on segment B

In contrast to the low (but increasing) probability of a major earthquake on segment A of the San Andreas fault, the central segment B (fig. 1) of the fault appears to have very low potential for producing a major earthquake in the near future. Among the segments of the San Andreas fault, the central segment is uniquely characterized by the occurrence of numerous small-magnitude (less than 5) earthquakes. This segment is presently moving in rigid block motion, principally by aseismic slip (fault creep). No detectable strain has accumulated in the crust adjacent to the fault since at least the mid-1880's. Either this segment of the fault has maintained itself in a critical equilibrium, on the verge of rupturing in a large earthquake for over a century, or fault creep effectively accommodates the plate motion.

Most scientists who have studied this segment favor fault creep as the likely way in which the stress is relieved.

Probability of earthquakes on segment C

The short-term risk of a major earthquake on either the south-central segment C (fig. 1) or southern segment D (fig. 1) of the San Andreas fault is considered to be significantly greater than it is to the north. Estimates place the annual probability of such an event between 2 and 5 percent per year. Several independent lines of evidence contribute to this assessment.

1. The mean recurrence time for major earthquakes on a portion of the 1857 break has been determined from the record of ancient earthquakes preserved in a marsh at Pallett Creek, near Palmdale, California. The mean frequency of fault offsets is one event every 140 years. At this site, the 124-year interval since the last event in 1857 is approaching the mean time interval between events.

2. Analysis of long-term earthquake rate variations also suggests that the risk of a major earthquake is high. Observed changes in earthquake frequency follow the same cyclic pattern described above for the northern San Andreas fault system. In the broad region surrounding the 1857 earthquake, seismicity has apparently increased to a level comparable to that observed along the northern segment preceding the 1906 earthquake since the early part of the 20th century (fig. 3). Thus, the pattern observed along the south-central segment (C, fig. 1) appears to be more advanced in its development by about 50 years than is the northern segment (A, fig. 1). This high level of seismicity also can be expected to continue up to the repeat of an 1857-sized event. Each of these lines of evidence suggests that a major earthquake may occur sooner along the south-central segment of the fault than along the northern segment. However, these time estimates can only be given in decades, not months or years.

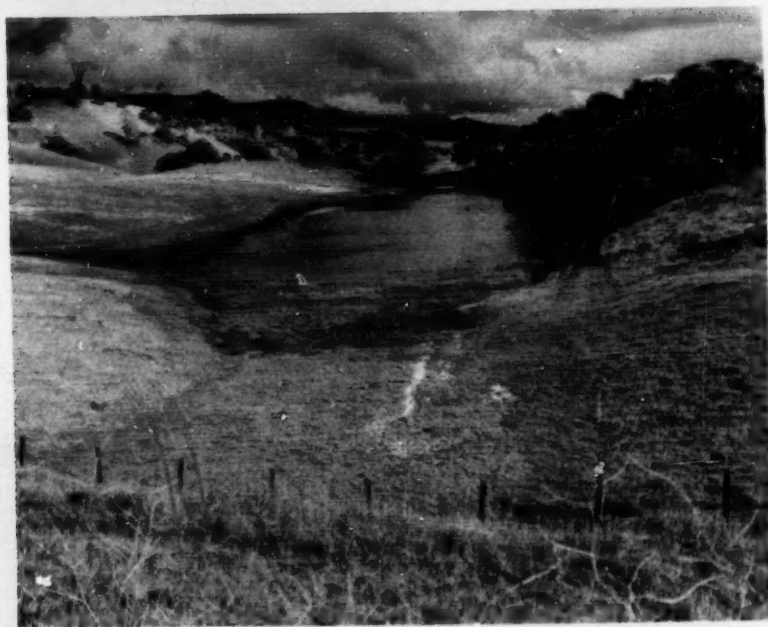
The San Andreas Reservoir lies in a valley along the San Andreas fault zone. San Francisco is in the upper right.

3. Frequent surveys of geodetic networks represents one very promising approach to the problem of detecting short-term anomalous crustal movements preceding damaging earthquakes. Data collected since 1973 from five of seven observation networks in southern California suggest that a regional increase in strain may have occurred in 1978-79. This short-term variation in the longer term strain accumulation pattern was most pronounced in the Palmdale network, where adjustments in the strain field occurred that brought the fault significantly closer to failure. Although there was no apparent correlation between this regional strain episode and detailed seismicity patterns recorded within the networks, the change coincides with a statewide increase in magnitude 6 and greater earthquake activity. The significance of this coincidence is unknown at present.

Sag ponds are typical features found along depressions in the San Andreas fault. (Photograph by Robert E. Wallace.)

Probability of earthquakes on segment D

The earthquake potential of the southernmost fault segment (D, fig. 1) is less well defined because no major earthquakes are known from either the historic record or detailed geologic studies. However, the risk here should be considered to be high. This segment of



the fault, like the other two segments that have ruptured causing earthquakes, is locked at the surface, has elastic strain accumulating across it, and produces very small earthquakes. It is embedded within the most seismically active area in California, one that has produced magnitude 6 and greater earthquakes at a nearly constant rate during the historic period. Thus, the features believed to be symptomatic of high potential for major earthquakes elsewhere on the San Andreas fault appear to be present here.



The Earthquake Hazards Reduction Program

The U.S. Geological Survey is attempting to refine the estimates of short-term risk given in the preceding paragraphs through the Earthquake Hazards Reduction Program, a program of monitoring and research that includes several scientific disciplines. Instrumental and survey networks that include over 400 telemetered seismographic stations and 25 geodetic networks containing hundreds of survey lines, for example, now cover the San Andreas fault system in its entirety. Because of its scale and fundamental emphasis, this network is most likely to succeed in developing the ability to predict the occurrence of the largest earthquakes in the San Andreas system—the magnitude 7 to 8 events that form the major hazard to human life and property. The instrumented region also includes between 5 and 10 sites where repeated moderate earthquakes have occurred and thus provides a number of opportunities to study the process accompanying these small but more frequent earthquakes.

◀ Long-term continuous activity of the San Andreas fault is shown well by the quarter of a mile offset of a stream on the Carrizo Plains, central California. The block on the near side of the fault is moving to the left (south); the block on the far side is moving to the right (north). Such motion is called right-lateral strike slip. (Photograph by Robert E. Wallace.)

News From the Observatories

Seismology in Iraq

*By Khalid J. Fahmi,
Seismology Unit,
Scientific Research Council,
P.O. Box 255,
Baghdad, Iraq*

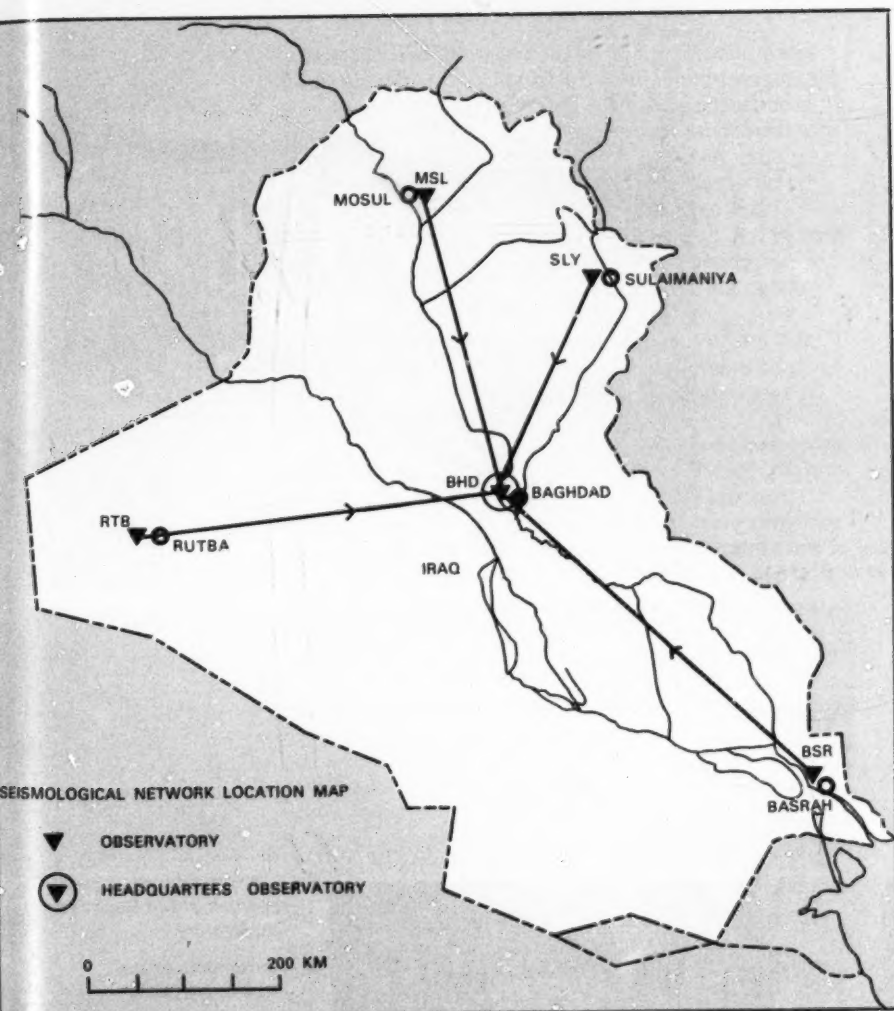
Introduction

Investigations of the seismicity and seismotectonics of Iraq and its bordering region repeatedly have stressed the need to establish a network of observatory-type seismological stations. Such an observational network would be invaluable in providing earth scientists and engineers with data on regional and local seismicity in Iraq.

In May 1976, a committee of specialists put forward a project proposal to the Government of Iraq for establishing a seismological network. This was approved and the Iraqi Seismological Network (ISN) project came into being. This development meant the creation of an organizing body to take full responsibility of the ISN. Thus, the Seismology Unit was founded in February 1977 as part of the Iraqi Scientific Research Council.

The Seismology Unit

The basic task of this organization has been to supervise the construction of the ISN component observatories, the operation and maintenance of existing instruments, and the reporting and exchange of seismological data. Equally important, the Unit endeavors to enrich Iraqi practice and expertise with new advances in seismological theory and observation through conducting sound scientific research. These activities are complemented by field studies in specific areas with the aim of providing technical advice assessing seismic hazards and reducing earthquake risk.



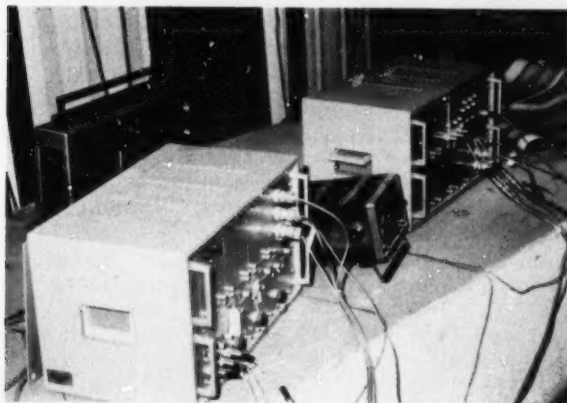
Location map for stations in the Iraqi Seismological Network.



View of station
site at Baghdad. ►



▲ A recent local earthquake
recorded at the Baghdad
Observatory.



◄ Instruments at the
Baghdad station.



The Iraqi Seismological Network

The planned ISN will consist of five observatories at Baghdad, Mosul, Sulaimaniya, Rutba, and Basrah. The station at Baghdad has been in routine operation since July 1979. The Mosul seismological observatory was inaugurated July 1981, has since been undergoing experimental operation and testing, and should enter routine reporting procedure by July 1982. Sulaimaniya and Rutba, on the other hand, are in their final stages of construction and will be ready for experimental operation by the end of 1982. Basrah is still in the design stages.

Although the various detailed aspects of the ISN project are dealt with in other publications, a brief outline of existing instrumentation is nevertheless called for here.

Baghdad (BHD) is equipped with a three-component short-period (1.0-second) system and a three-component long-period system (with a 10 to 20-second period, presently set to 10 s). The long-period seismograph is actually a short-period instrument, the response of which has been modified electronically to 10 or 20 seconds. Recording is done on a 2- x 3-channel rectilinear ink-paper recorder.

A similar vertical long-period system is operating at Mosul (MSL) with a Wood-Anderson filter giving displacement characteristics. Recording is performed by a helical drum recorder supplied with heat-sensitive paper. In addition, MSL has a three-component intermediate-period system. Although the seismometer period is set to 5.0 seconds, the system can be employed as a long-period seismograph, provided it is set to an appropriate amplifier-filter combination.

Because Baghdad is the effective headquarters of the network, it will ultimately house the processing center in addition to being equipped with high-precision instruments for special applications such as rapid deployment field investigations, strain measurements, and structural-vibration monitoring and analysis.

As far as the data acquisition and processing system is concerned, a powerful computer suite consisting of 0.5 megabyte input/output core memory plus an extended 120 megabyte mass store along with a number of versatile peripheries were installed in 1981. The system is presently undergoing various tests and software implementations and should be available for off-line processing and analysis by late 1982.

It is anticipated that the first phase of the ISN project, which involves individual five-station tape recording and processing, will be in full operation by late 1983.

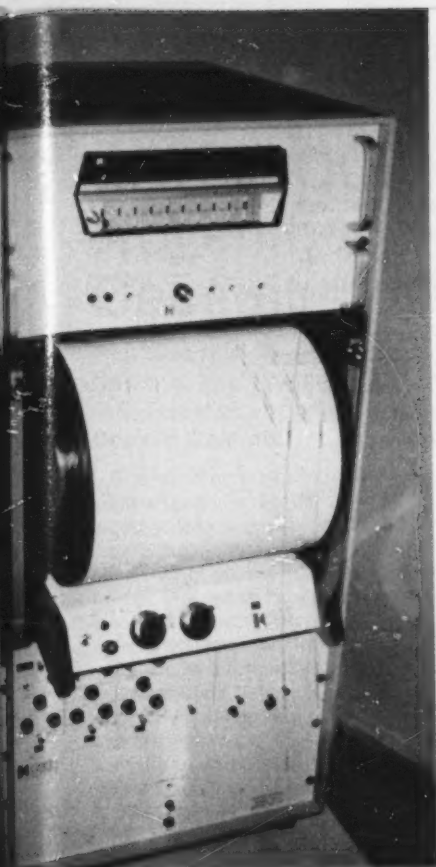
Current Research

An important objective for the Unit, besides routine observations, has been the investigation of natural earthquakes and artificial explosions. The following are some of the more important research areas currently being undertaken:

- Seismicity and seismotectonics of Iraq.
- Recent and historical seismicity of the Arab world.
- Field monitoring, macroseismic investigations, and source-parameter studies of medium to large recent local earthquakes.
- Induced seismicity of Iraqi dams.
- Continuous appraisal of ISN instrumentation and capability directed towards future subnetwork expansion and array design.
- Designing a Long Profile Explosion Experiment to investigate the crust and upper mantle beneath Iraq.
- Assessing seismic hazards and evaluating earthquake risk in Iraq.

Arab and International Cooperation

The Unit works towards creating, developing, and strengthening inter-Arab and international cooperation in geophysics in general and in seismology in particular. A prime objective for the Unit centers around participating in the establishment and eventually the running of the long-awaited Standardized Arab Seismological Network (SASN) and the Regional Arab Processing Center (RAPC). Both of these projects originally were suggested and adopted as resolutions in the First Arab Seismological Seminar (ASS) which was held in Baghdad, Iraq, in December 1978. In the Second ASS meeting held last October in Rabat, Morocco, the whole program (which by then had been submitted in the form of a prefeasibility study by the United Nations Educational, Scientific, and Cultural Organization to the Arab Fund for Economic and Social Development and the Islamic Development Bank) received unanimous approval and support by the conference. As a result, a group of international authorities were commissioned to prepare an actual



▲ View of station site at Mosul.

◀ Instruments at the Mosul station.

feasibility study for the project. The study is presently underway, and Dr. Robin Adams of the International Seismological Center (ISC), England, has been named secretary to the committee.

On an international level and as part of an overall policy of mutual cooperation, the Unit has joint research and training protocols with Turkey, Yugoslavia, and Japan. Contacts are underway for similar agreements with other countries engaged in observational practice and research.

Since 1978, the Unit has been a member of the ISC and is in the process of applying for provisional admission to the International Union of Geodesy and Geophysics and the International Association of Seismology and Physics of the Earth's Interior. Efforts also are being concentrated on participating in the commemorations of the International Geophysical Years.

Other Activities

As far as academic research is concerned, the Unit maintains close contacts with Iraqi universities where geophysical and seismological studies are being carried out as part of a growing postgraduate research program.

Staff in the Unit also have participated in and have attended a number of conferences on seismicity, tectonics, earthquake risk, and prediction; the Unit encourages exchange of geophysical information and ideas at such local, regional, and international meetings.

Since its inception, the Unit has provided consultations and technical advice to various local and international organizations concerned with major construction projects in Iraq. Many problems involving seismic engineering parameters have been investigated, and a better understanding of the country's seismic macro- and microzonation has been attained by both seismologists and engineers. This has led to developing an insight into evolving sound practice for earthquake resistant design.

The Unit aspires to develop into a quality national research center for theoretical and applied geophysics. It is hoped that this major goal will be achieved in the near future.

Site Information for Stations of the Iraq Seismological Network

Station Name	NEIS/ISC code	Latitude (North)	Longitude (East)	Elev. (ft)	Date Opened	Foundation (Geologic Age)
Baghdad	BHD	33°16'28".0	44°23'09".0	104.9	July 1979	Alluvium (Recent)
Mosul	MSL	36°22'54".0	43°08'53".7	797.9	July 1981	Sandstone (Miocene).
Sulaimaniya	SLY	(35.6°)	(45.5°)	N/A	Under construction.	Limestone (Cretaceous).
Rutba	RTB	(33.1°)	(40.3°)	N/A	Under construction.	Limestone (Jurassic).
Basrah	BSR	(30.6°)	(47.8°)	N/A	Under design.	Alluvium (Recent)

*NEIS = U.S. National Earthquake Information Service.

EARTHQUAKES

November- December 1981

*By Waverly J. Person,
National Earthquake Information Service,
U.S. Geological Survey,
Denver, Colorado*

The last 2 months of the year were somewhat active, seismically speaking, including three major earthquakes (7.0-7.9) during the month of December. The first of the major quakes was in the Aegean Sea on December 19, and the other two were in the South Pacific in the Kermadec Islands on December 24 and 26.

Earthquake fatalities were experienced in Pakistan on December 12, and considerable damage was reported in the eastern Caucasus.

In the United States, a number of earthquakes were experienced, but no significant damage occurred.

Colorado

A minor but alarming earthquake occurred in the north-central part of this State on November 1 at 8:03 p.m. m.s.t. The magnitude 3.1 tremor was centered in the Evergreen area about 22 miles southwest of Denver. The effects registered V on the Modified Mercalli Intensity Scale (MM) and were experienced in the Conifer, Evergreen, and Pine Junction areas. It was also felt in other parts of Jefferson County and in parts of Clear Creek and Park Counties.

Nevada

Four earthquakes were located and reported felt in this State. The first quake, on November 4 at 3:47 a.m. P.s.t., had a magnitude of 3.3 and was located about 9 miles south of Reno. MM V effects were experienced at Reno, and MM IV effects occurred at Silver City. The earthquake was also felt in the Carson City area.

The western part of the State experienced two light earthquakes, the first on December 1 at 8:19 a.m. P.s.t. and the second on December 6 at 11:48 p.m. P.s.t.; the earthquakes had magnitudes of 4.5 and 4.1, respectively, and were located about 6 miles north of Luning. MM V effects were experienced at Luning from the first shock, and MM IV effects were felt from the second shock. Both earthquakes were also felt at Gabbs, Hawthorne, and Mina.

The fourth earthquake, on December 28 at 2:46 p.m. P.s.t., had a magnitude of 3.6 and was located in the southeastern part of the State about 72 miles north of Las Vegas. MM IV effects were noted at Las Vegas, and the earthquake was felt in Clark and Lincoln Counties. It was also felt at Toquerville, Utah, and Temple Bar, Arizona.

Texas

The east-central part of this State was shaken by a minor earthquake on November 6 at 6:37 a.m. c.s.t. The magnitude 3.2 shock was located about 28 miles south of Tyler near Jacksonville. It was felt in the areas of Jacksonville and New Summerfield (MM IV).

Alaska

This State experienced a number of earthquakes during this reporting period; the two largest occurred on November 9 at 5:45 a.m. A.s.t. and December 30 at 4:01 a.m. A.s.t. The first had a magnitude of 5.3 and was centered in the Fox Islands, Aleutian Islands, about 56 miles southeast of Unalaska. MM IV effects were noted at Unalaska.

The second earthquake was centered in central Alaska about 28 miles southwest of Fairbanks. MM V effects were experienced at Ester, and MM IV effects were felt at Fairbanks. The earthquake was felt from Delta Junction into the Ester-Fairbanks area. This earthquake was preceded by a magnitude 4.2 earthquake at 3:47 a.m. A.s.t.; MM IV effects were felt at Fairbanks.

Hawaii

This State experienced a number of earthquakes during the last 2 months of the year. The three largest occurred on November 10 at 3:03 a.m. H.s.t., November 19 at 7:33 p.m. H.s.t., and December 7 at 5:39 p.m. H.s.t. The first and largest earthquake, a magnitude 5.3, was located about 9 miles south of Volcano and was felt over much of the island. There were no reports of damage. The second earthquake had a magnitude of 4.4 and was located about 25 miles northwest of Hilo. It was felt on the southeastern part of the island. The last earthquake had a magnitude of 4.1 and was located near the west coast of the island, about 6 miles north of Huehue. It was felt on the northwestern part of the island.

California

This State experienced a number of earthquakes during this reporting period, but most were below magnitude 4. The southern part of the State was shaken by a light earthquake on November 10 at 2:35 p.m. P.s.t. The magnitude 4.6 earthquake was located about 25 miles south of Bakersfield. MM V effects were noted at Bakersfield, Mettler, and Pumpkin Center. It was also felt in other parts of Kern County and in parts of Los Angeles, Santa Barbara, San Bernardino, and Ventura Counties.

The northern part of the State was shaken by an earthquake on November 11

at 9:46 a.m. P.s.t. The magnitude 4.8 earthquake was centered near the coast about 16 miles southwest of Petrolia. MM III effects were experienced in the areas of Alderpoint, Fields Landing, Honeydew, and Whitehorn in Humboldt County.

Washington

This State had two earthquakes reported felt during this reporting period. The first, on November 12 at 10:10 a.m. P.s.t., was located about 28 miles northeast of Seattle and was felt widely. MM IV effects were experienced in the area of Freeland, Langley, Port Ludlow, Marysville, Mukilteo, Poulsbo, and Silvana. MM III effects were noted in the Everett and Seattle areas. The earthquake was also felt in parts of Jefferson, King, and Skagit Counties.

The second earthquake was on November 26 at 4:30 a.m. P.s.t. The magnitude 3.1 tremor was located about 16 miles northwest of Seattle and about 31 miles southwest of the above earthquake. MM IV effects were experienced in the areas of Indionola, Port Orchard, and Seabeck. The earthquake was also felt in other areas of Kitsap County and in parts of King, Mason, Pierce, and Snohomish Counties.

Egypt

A series of earthquakes struck the Aswan area in the southwestern part of this country during the month of November. The largest was a magnitude 5.2 on November 14. At least 11 buildings were reported damaged, but there were no reports of injuries.

Caucasus

The eastern part of the Caucasus was struck by a moderate but damaging earthquake on December 2. The magnitude 5.2 earthquake was centered about 93 miles northwest of Baku in the Ismailly area.

Many houses were reported destroyed or damaged in the Ismailiy area.

New Mexico

A minor earthquake occurred in a sparsely populated area of the west-central part of this State on December 4 at 1:51 a.m. m.s.t. The magnitude 2.8 tremor was located about 90 miles southwest of Albuquerque and was felt in areas south of Grants.

Idaho

The southeastern corner of this State experienced a light earthquake on December 9 at 1:15 a.m. m.s.t. The magnitude 4.1 earthquake was located about 43 miles southeast of Pocatella in the Soda Springs area. MM V effects were experienced at Conda and Soda Springs. The earthquake was also felt in the areas of Lava Hot Springs, Paris, and Pocatello.

Pakistan

The northwestern part of this country experienced a light but killer earthquake on December 12. The magnitude 1.7 earthquake was centered about 124 miles west of Quetta. Six people were killed, and 12 people were injured in the Karak area.

Aegean Sea

A magnitude 7.2 earthquake occurred in the Aegean Sea on December 19 about 78 miles northeast of Athens, Greece, causing damage on Lesbos and Skiros and also in western Turkey. The earthquake was felt strongly throughout most of Greece, in southern Bulgaria, and in western Turkey. Many aftershocks have followed. A magnitude 6.5 earthquake occurred in this area on December 27 (probably an aftershock) causing damage to 10 houses on Evvoia. This earthquake was again felt strongly in many parts of Greece. It was also felt in the Izmir, Turkey, area.

Kermadec Islands

A series of earthquakes occurred in these remote islands of the South Pacific. Two of these were major earthquakes, a magnitude 7.0 on December 24 and a magnitude 7.1 on December 26. Both earthquakes were centered about 870 miles northeast of Wellington, New Zealand. There were no reports of damage or wave activity.

U.S. Activity*

Alaska	12
Arizona	1
California	10
Colorado	1
Hawaii	26
Idaho	1
New Mexico	1
Nevada	4
Texas	1
Utah	1
Washington	2
Total	60

*Felt earthquakes as reported from many sources.

Preliminary Locations

Date	Origin time	Region	Coordinates		Depth (km)	Magnitude
			Latitude	Longitude		
Nov. 2-----03	03	00.1	Colorado-----	39.5 N 105.3 W	1	¹ 2.8 M _L
Nov. 4-----11	47	19.1	Nevada-----	39.4 N 119.8 W	5	3.3 M _L
Nov. 6-----12	36	40.7	Central Texas-----	32.0 N 95.2 W	5	² 3.2 m _b L _g
Nov. 9-----16	45	06.4	Fox Islands, Aleutian Islands.	53.3 N 165.8 W	33	³ 3.3 M _S
Nov. 10-----13	02	57.0	Hawaii-----	19.3 N 155.2 W	8	⁴ 5.3 m _b
	22 34	35.5	Southern California.	35.0 N 119.1 W	3	4.6 M _L
Nov. 11-----17	46	07.5	Near coast of northern California.	40.2 N 124.5 W	5	4.8 M _L
Nov. 12-----18	10	24.9	Washington-----	48.0 N 122.4 W	28	3.9 M _L
Nov. 14-----09	05	30.4	Egypt-----	23.9 N 32.7 E	10	5.2 M _S
Nov. 20-----05	32	57.9	Hawaii-----	20.9 N 155.4 W	10	4.4 M _L
Nov. 26-----12	30	00.7	Washington-----	47.7 N 122.6 W	25	3.1 M _L
Dec. 1-----16	18	50.0	California- Nevada border region.	38.6 N 118.2 W	11	4.5 M _L
Dec. 2-----00	51	36.4	Caucasus-----	40.9 N 48.3 E	33	5.2 m _b
Dec. 4-----08	51	24.6	New Mexico-----	34.4 N 108.2 W	5	2.8 M _L
Dec. 7-----07	47	51.6	California- Nevada border region.	38.7 N 118.2 W	6	4.1 M _L
Dec. 8-----03	39	27.2	Hawaii-----	19.8 N 156.0 W	41	4.1 M _L
Dec. 9-----08	15	04.8	Eastern Idaho-----	42.7 N 111.5 W	7	4.1 M _L
Dec. 12-----20	26	46.6	Pakistan-----	29.9 N 66.9 E	33	4.7 m _b
Dec. 19-----14	10	52.9	Aegean Sea-----	39.4 N 25.1 E	15	7.2 M _S
Dec. 24-----05	33	21.5	Kermadec Islands_	30.0 S 177.7 W	33	7.0 M _S
Dec. 26-----17	05	32.8	-----do-----	29.8 S 177.9 W	33	7.1 M _S
Dec. 27-----17	39	16.7	Aegean Sea-----	39.0 N 24.8 E	33	6.5 M _S
Dec. 28-----22	45	42.1	Southern Nevada_	37.2 N 115.0 W	5	3.6 M _L
Dec. 30-----14	00	33.8	Central Alaska-----	64.6 N 148.1 W	33	5.2 M _L

¹Richter magnitude.

²Magnitude from Love waves

³Magnitude from surface waves.

⁴Magnitude from body waves.

U.S. Geological Survey Publications

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P 1240-B. Facing geologic and hydrologic hazards—Earth-science considerations.
Edited by W. W. Hays. 1981. p. B1-B108.
\$7.50.

Earth-science information is assembled to answer some of the broader questions about earthquakes, floods, ground failures, and volcanic eruptions. Actions to reduce losses are suggested for planners and decisionmakers. The first of this series of Earth-Science Special Reports, *Synthetic Fuels Development—Earth-Science Considerations*, was published in 1979 and was not identified as part of the U.S. Geological Survey Professional Paper series. When the earlier report is reprinted, it will be designated as U.S. Geological Survey Professional Paper 1240-A. Subsequent reports in the Earth-Science Special Report series will be designated as lettered chapters in Professional Paper 1240.

P 1250. The 1980 eruptions of Mount St. Helens, Washington. Edited by P. W. Lipman and D. R. Mullineaux. 1981 (1982). 844 p.; 1 plate in pocket.
\$35.

The reawakening of Mount St. Helens Volcano in March 1980 and its catastrophic eruption of May 18 surely will rank among the most significant geological events in the United States in the 20th century. In this hard bound book, 62 separately authored reports summarize results through 1980 of studies of volcanic events, geophysical monitoring of activity, and studies of volcanic deposits, effects, and potential hazards. The volume is dedicated to David A. Johnston, the United States Geological Survey volcanologist who was swept away by the May 18 eruption while manning a geophysical monitoring outpost. Illustrations consist of 470 figures, including many photographs and line drawings in color, 117 tables, and a colored geologic map (scale 1:50,000) showing proximal deposits and features of the 1980 eruptions. Nontechnical introductions to each major section, in conjunction with the extensive illustrations, make the volume useful for readers lacking formal geologic training.

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Head of a large landslide along a fracture zone near the epicenter of the magnitude 7.0 Varfo earthquake in eastern Turkey on August 19, 1966.
(Photograph by Robert E. Wallace.)

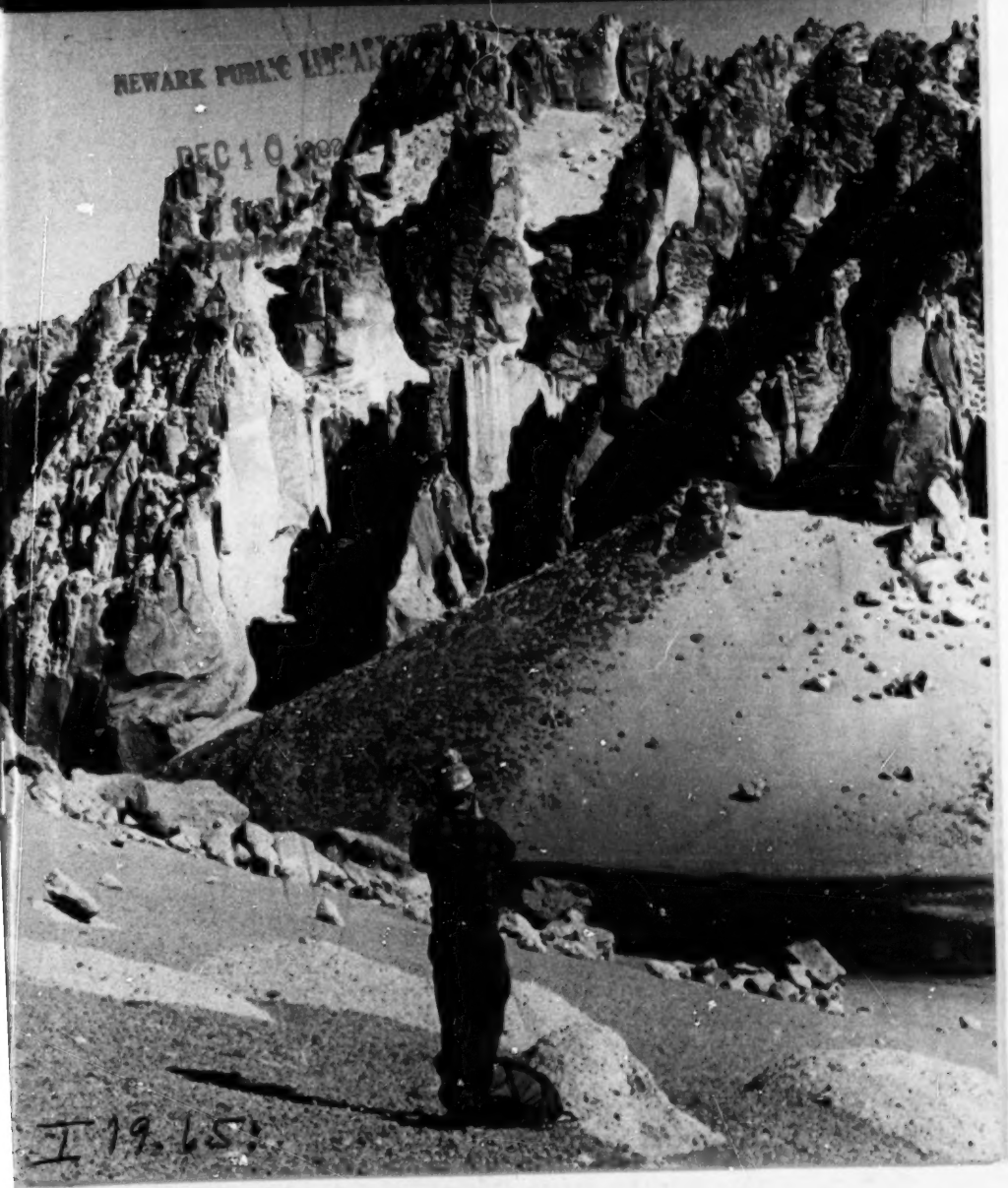
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UNITED STATES
DEPARTMENT
OF THE
INTERIOR
GEOLOGICAL
SURVEY

Earthquake Information Bulletin

July-August 1982, Volume 14, Number 4



**UNITED STATES DEPARTMENT OF THE
INTERIOR**

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

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Earthquake Information Bulletin



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Cover: Massive ash flows on the flanks of the Cerro Galan Caldera, northwest Argentina. The 24-mile-diameter caldera was identified only in 1973 by means of photographs taken aboard the Skylab spacecraft. This photograph was taken by Peter Francis. (See the first article in this issue.)

The Cerro Galan Caldera, Argentina

*By Peter Francis,
Department of Earth Sciences,
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Milton Keynes, England*

In this age of space technology, it is natural to suppose that Earth is so well explored that nothing remains to be discovered, let alone major volcanic structures. This is not the case, however. Spacecraft imaging, particularly by Landsat, has enabled us to recognize a number of volcanic structures which are amongst the largest on Earth.

These are no ordinary volcanoes. Rather than tall conical mountains like Vesuvius or Mount St. Helens, they are vast shallow depressions (calderas), sometimes with central mountains. They are often so large that one can walk or drive right across such a structure without being aware of its existence; it is not easy to image a single volcano with a crater as large as, say, the State of Rhode Island. This is where spacecraft imagery comes into its own; the synoptic view enables scientists to stand well back (many hundreds of miles) and see such structures in their entirety.

The existence of the Cerro Galan Caldera in north-west Argentina first came to light when scientists at the Los Alamos Laboratory, New Mexico, were studying photographs taken with a hand-held camera by astronauts aboard the Skylab spacecraft in 1973. They picked out the caldera as a 24-mile-diameter elliptical structure with a central mountain complex, heavily mantled in snow. Unaware of their work at the time, my colleague M. C. W. Baker and I at the Open University in England recognised the same caldera while making a specific search for similar structures on Landsat imagery of the central range of the Andes, an area whose volcanology we had been studying for a

Landsat image of the Cerro Galan Caldera, Argentina. The snow-covered resurgent center of the caldera is conspicuous. The deeply gullied rocks around the northern half of the caldera represent the vast apron of ashflows erupted from it. The caldera is about 25 miles wide from north to south.



number of years. Examination of the literature soon revealed that the caldera had not previously been recognized by group studies, although the area had been covered by aerial photography and geologists had visited the region and even made a traverse across it from west to east. The caldera had simply been camouflaged by its own size.

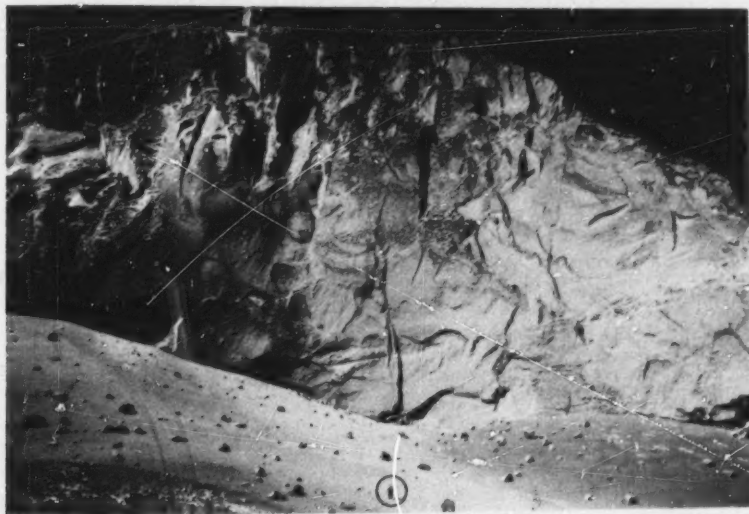
Although the Cerro Galan Caldera was new to science, the satellite imagery showed that it belonged to a class of structures known as *resurgent calderas*. These are produced by the catastrophic eruption of enormous volumes of silicic (rich in quartz) magmas in the form of pyroclastic flows (incandescent ash flows); this causes the roof overlying the magma chamber to collapse and form a caldera. Subsequent intrusion of fresh magma causes the caldera floor to be heaved up once more, forming the distinctive central mountain complex, or *resurgent center*. Much the best-known example of this kind of volcanism is the 1-million-year-old, 12-mile-diameter Valles Caldera in New Mexico, from which the series of ashflows known as the Bandelier Tuff was erupted. The total volume of ashflows erupted is measured in hundreds of cubic miles.

After two preliminary visits to the Cerro Galan Caldera in 1978 and 1979, it became painfully obvious that studying the caldera on the ground was going to be no easy task. Apart from its great size, the caldera is also rather inaccessible; its rim rises to 17,200 feet, its floor is at a height of 14,850 feet, the summit of the resurgent center is about 20,000 feet high, and the nearest point accessible by road is the hamlet of Antofagasta de la Sierra, about 30 miles from the western rim. The logistics of studying the caldera were much more difficult than could be handled in terms of ordinary academic fieldwork, so an expedition of 30 British and Argentinian scientists evolved. Most of the team were to provide logistic support, so that the geologists could work in the farthest corner of the caldera.

Preliminary ages of volcanic rocks from Cerro Galan were calculated from radiometric measurements. (Determining the amount of a radioactive element in a rock and its decay products allows us to measure geologic time because we know from laboratory experiments the rate at which the radioactive disintegration occurs.) The ages suggest that the first events in the evolution of the caldera took place between 5 and 10 million years ago, when volcanoes began to erupt on what are now the west flanks of the caldera. The products were mainly andesite and dacite lavas, depending on the chemical composition of the molten magma during the eruption; for example, dacite contains more silica than andesite and is



The expedition's principal camp within the caldera at an altitude of 15,000 feet. The mountains in the background form part of the western rim of the caldera.



The geologist (circled) at the bottom of the picture helps give an idea of the enormous scale of the Cerro Galan ashflows. These cliffs reach heights of 1,200 feet. Most of the ashflows seen here were erupted early in the history of the caldera.

said to be a more "acid." (The term "andesite" was, in fact, first applied to the chemical and mineralogic composition of certain volcanic rocks from the Andes of South America.)

These eruptions formed sizeable mountains such as the 18,800-foot-high Cerro Colorado. Basaltic (more basic) volcanism also commenced at about the same time in the valley of Antofagasta de la Sierra and led to the formation of numerous scoria (cinder) cones and lava flows. The basaltic activity appears to have continued at the same time as the caldera-forming events. The youngest basalt flows and cones, which are clearly younger than the caldera, may be only a few thousand years old.

Major eruptions of ashflows commenced about 5 million years ago. At least three major ashflow complexes were erupted prior to the formation of the present caldera, and these accumulated to a total thickness exceeding 1,000 feet. Many of the valleys in the western part of the caldera expose this complete thickness in magnificent vertical cliffs tinged pink, brown, and white. Erosional intervals between the major ashflows are conspicuous because they form distinct terraces, or breaks, in the cliffs which can be traced over large areas. Although only predecessors to the main caldera-forming event, these ashflows themselves present a number of characteristics fascinating to geochemists. By far the greatest proportion of the ashflows is made up of fragments of "ordinary" pumice, the frothy light-weight rock characteristic of silica-rich volcanic eruption. Among these ordinary fragments, or clasts, there is also an exceedingly interesting distribution of much rarer "mixed" clasts, in which light-colored acid pumice is intermingled with darker colored, more basic pumice. The presence of these mixed clasts suggests that during their eruption, the deeper, most mafic parts of the magma chamber were intermittently tapped, and they may provide some important pointers towards the original chemical stratification within the magma chamber.

Studies of the lithic clasts (fragments of older rocks torn from the sides of the vent) in the ashflows suggest that the early ashflows were derived from vents

The resurgent center of the caldera, as seen from the western rim. The whole of the central mountain massif is composed of a single ashflow. The highest peak visible reaches 20,000 feet. The topography within the caldera is subdued, due to the effects of frost shattering in a very arid environment. The effect has created a stark lunar landscape.



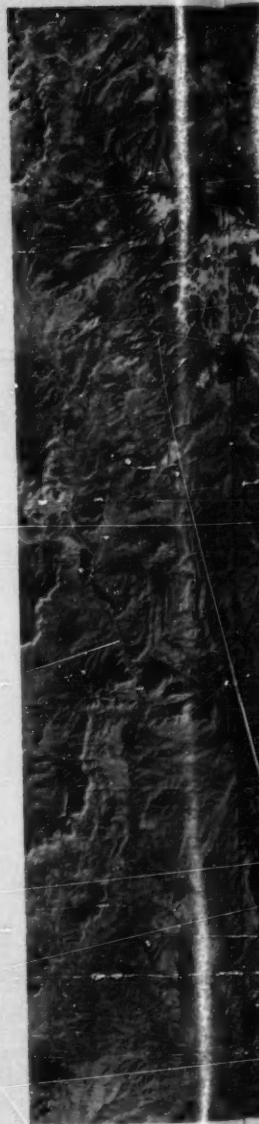
erupting from older vents located on the western flank of the present caldera; there may also have been one or more subordinate vents on the eastern flank.

The gigantic eruption which produced the present 25- by 20-mile caldera took place about 2.6 million years ago. At least 200 cubic miles of ashflows were erupted, which can still be identified today at distances of up to 40 miles from the caldera. On the flanks of the caldera itself, these ashflows are not particularly thick, forming a cap only 70 to 100 feet thick on top of the older series, but they travelled much further horizontally than any of the earlier flows, probably as a result of a different eruption mechanism. They are also quite different physically from the older flows, containing much finer grained clasts of pumice and rare small lithic clasts. Formation of the caldera itself commenced early within the eruption sequence, with the result that huge volumes of ashflows accumulated within the deepening basin. At present, these ashflows are exposed to a thickness of 0.75 mile in the resurgent center.

Immediately after the major eruption, the Cerro Galan Caldera was probably a simple open depression that soon began to fill up with sediments eroded from its walls. At one time, it may also have contained a substantial lake, of which the present Laguna Diamante is a small relic. Subsequently, resurgence of the center took place, arching the floor of the caldera and tilting the ashflows and their covering of sediments. It is not clear how much uplift took place, but it must have been at least 3,000 feet.

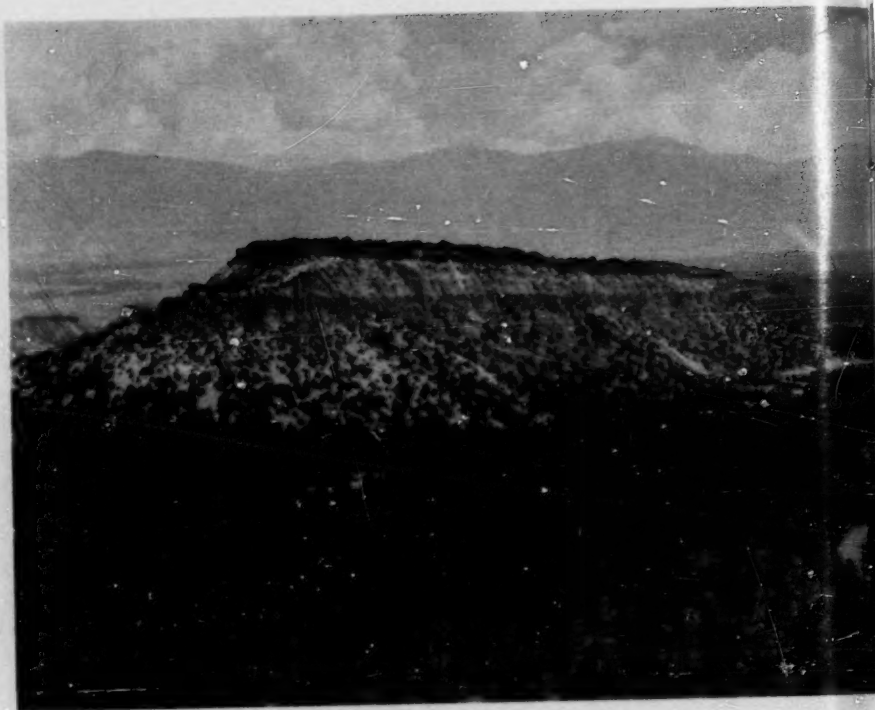
Since the upheaval of its center, Cerro Galan has been relatively peaceful. Small amounts of dacite lava have leaked up along the ring fractures in two or three places, the most recent leakages being within the last few tens of thousands of years, judging from the surface shape of the extrusions. Vigorous geothermal activity was manifested in numerous hot springs in and around the caldera. The impressive scale of this activity is demonstrated by the thickness of tufa deposits exposed today. (Tufa beds are abundant around the hot springs of Yellowstone National Park, Wyoming.) Hot springs still flow from a number of different sites, principally around the foot of the resurgent center, and provide welcome stopping places for mule trains venturing across the bleak and windswept caldera.

The hot springs are the only present evidence of volcanic activity in the area, and it is not clear whether or not Cerro Galan could be the site of major renewed activity. Studies of other caldera systems, coupled with the sheer scale of the magma chambers that underly them, suggest that they are the sites of





Landsat view of the Valles Caldera, New Mexico. This image was taken with the return beam vidicon (RBV) camera, which produces a resolution of about 100 feet, three times better than the more familiar multispectral scanner (MSS) image.



Valles Caldera in the Jemez Mountains of New Mexico is a smaller scale version of the Cerro Galan Caldera. It is 15 miles in diameter, and eruptions began to occur about 1 million years ago. Hot springs continue today on the western side of the caldera. (Photograph by Roy Bailey.)

thermal anomalies that have persisted within the Earth's crust for millions of years. Renewed activity is, therefore, possible at any time.

Although planned initially as a purely volcanological expedition, our studies of Cerro Galan may prove to be relevant in a quite different context. For many years, a sequence of land-deposited sediments, about 90 miles southeast of the caldera, had been known as a classic locality for Late Tertiary mammal fossils. These were so important that, as early as 1926, an expedition from the Chicago Field Museum of Natural History was sent there to collect fossils. Recently, a number of radiometric age determinations were made on volcanic ash beds within the sequence to pin down



the ages of the fossils and specifically to determine at what date North and South American fossils were united by the Isthmus of Panama.

The age determinations were made without knowledge of the sources of the ashes and were subject to unavoidable sources of error, such as contamination by fragments of material from older rocks. It is now clear that many of the ashes were derived from Cerro Galan, and detailed mineralogical and geochronological studies should make it possible to relate each of the ash marker horizons in the fossil-bearing sequence to a specific eruption in the Cerro Galan area. Thus, it may ultimately be possible to provide a well-documented time scale for the eruptions and to contribute to a better determination of the timing of mammal evolution in the Americas.

Further reading

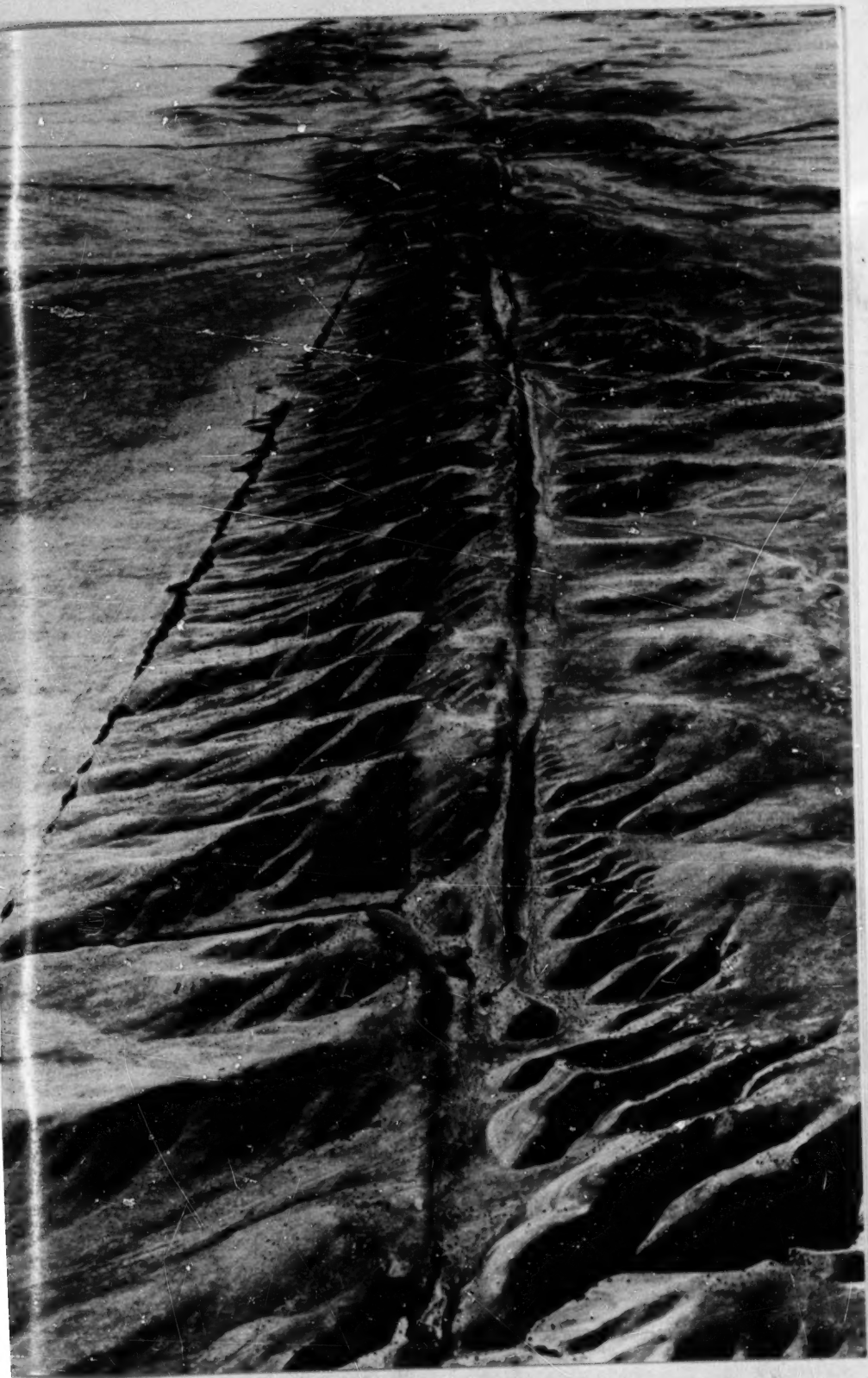
Francis, P. W., 1976, *Volcanoes*: Penguin Books, Harmondsworth, England, 368 p.

Southern California's Last Great Earthquake and Clues About the Next One

This year marked the 125th anniversary of the great Fort Tejon, California, earthquake of January 8, 1857. By digging large trenches across the segment of the San Andreas fault that broke near Palmett Creek and by studying contemporary records, Kerry Sieh of the California Institute of Technology has found evidence that the fault needs, on average, at least 125 years to prepare for its next catastrophic failure. The remainder of this wait, of course, could be anywhere in this century or the next.

The Fort Tejon earthquake occurred at a time when there were no dense networks of instruments either to detect evidence for an impending earthquake or to describe the characteristics of the actual event itself. Still, by ingenious detective work, we can actually find out quite a lot about the earthquake. Sieh's work in deep trenches across the fault shows evidence for repeated breaks along the southern San Andreas fault over the last 2,000 years. The average repeat time (recurrence interval) is about 140 years, but the movements are by no means as regular as clockwork; individual events are separated by anywhere from 50 to 300 years, and there seems to be no rhythm to these breaks.

The trough of the San Andreas fault is a strong topographic feature south along the Elkhorn Scarp of central California. The Carrizo Plains are on the right; Elkhorn Plains are on the left. (Photograph by Robert E. Wallace.)

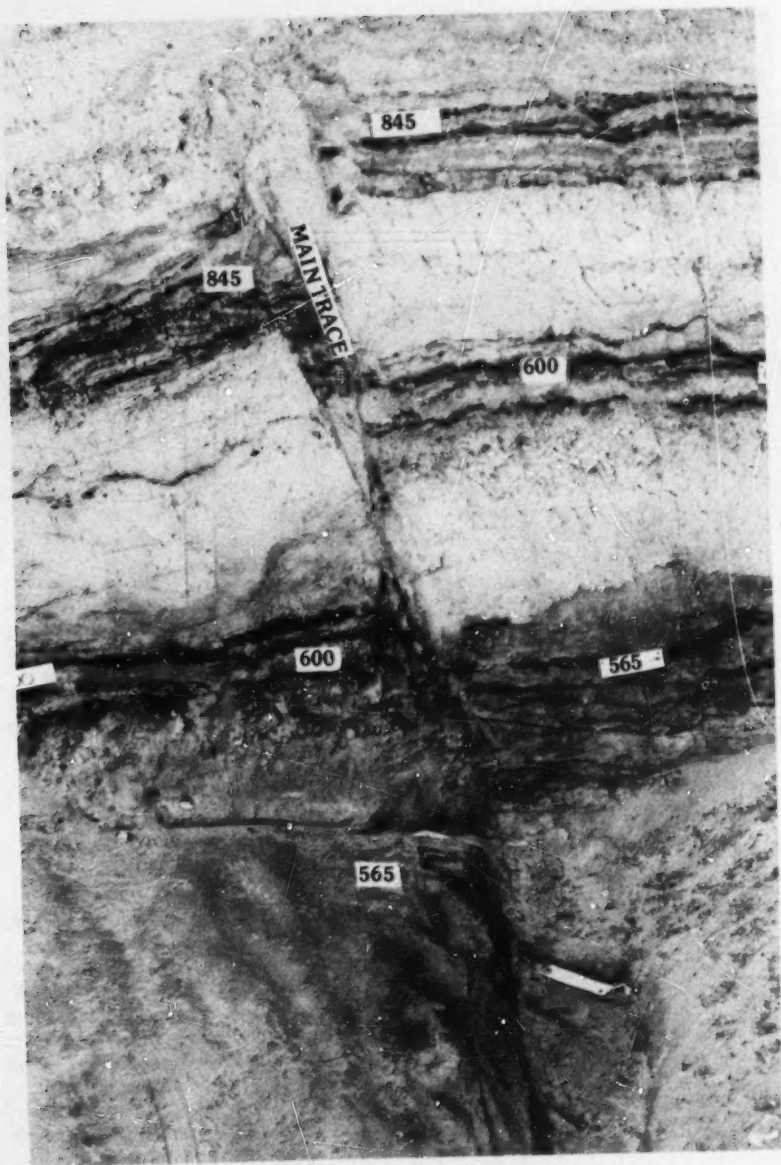


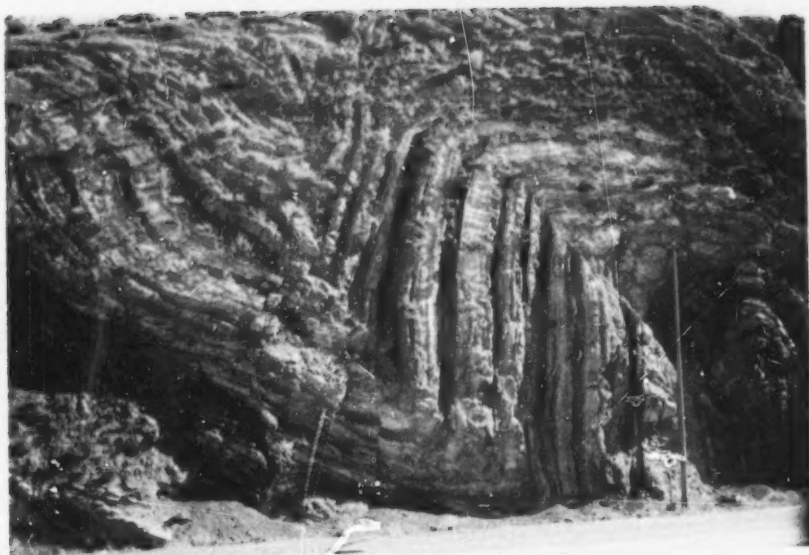
Another clue to what happened 125 years ago is given by newspaper accounts, diaries, letters, and biographies of the time gathered from all parts of California. By piecing together descriptions of the shaking with the times when these occurred, Sieh has been able to identify four foreshocks that struck California in the 9 hours before the main shock at 8:24 in the morning of January 9. People from Santa Barbara to San Francisco felt the last two foreshocks during the dawn hours. They appear to have occurred at the northern end of the 225-mile rupture near Parkfield and Cholame.

Sieh believes that these foreshocks may have triggered the great earthquake that followed. This same trigger was pulled on the same segment of the San Andreas fault south of Parkfield by magnitude 5.5 to 6 earthquakes in 1901, 1922, 1934, and 1966 but without precipitating another great earthquake. The reason was that the fault was probably not primed. This is achieved by the slow grinding of the Pacific and North American crustal plates past each other. To the north of Parkfield, the two sides of the fault *creep* by one another, which does not produce earthquakes. To the south of Parkfield, the fault is *locked* and moves only through infrequent earthquakes. Seismologists now believe that a single irregularity (or *asperity*) on the fault, such as a bend or an offset, can control locking and rupture along an entire segment of the fault.

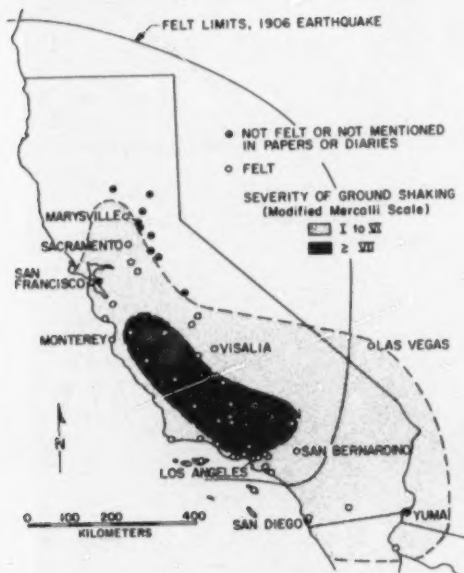
According to Sieh's model, in 1857, foreshocks near Parkfield may have broken through the asperity at Parkfield and driven into an asperity at Cholame. Here, the buildup of strain since the last great earthquake may have become so great that within a few hours this asperity broke, too. Nothing stopped the Fort Tejon earthquake until it ran into a fork in the fault system (possibly another asperity) northwest of San Bernadino. A disturbing consequence of this model, of course, is that the Parkfield earthquakes that have occurred during this century are like repeated hammer blows on a wedge—so far, without effect.

At Pallet Creek, south of Palmdale, subtle movements of the San Andreas fault over the past 2,000 years can be detected in trenches dug through river gravel and silt. The trench is a vertical section through the main trace of the fault (dark line running from top to bottom). Fault movement, probably caused by earthquakes, is identified by the offsetting of the horizontal layers of gravel and silt. The numbers on the cards represent the age of wood matter in the layers that has been dated by the carbon-14 method.





Near Palmdale, 40 miles northeast of Los Angeles, the San Andreas fault is easily distinguished in road cuts because the rocks are contorted and fractured.



Isoseismal map for the 1857 Fort Tejon earthquake compiled from historical documents by Kerry Sieh and Duncan Agnew. Open circles are locations where effects were felt; solid circles are locations where the earthquake was not felt; stippling shows the approximate area in which damage occurred.

Allan Lindh and his colleagues at the U.S. Geological Survey in Menlo Park, California, have been keeping a close eye on the Parkfield area to see if it might be even feasible to detect precursors to earthquakes in this area. Some evidence exists that the continuous slow creep on the fault accelerated to perhaps 10 times its normal rate before the 1966 earthquake. And, also, in the final 4 hours, there were foreshocks before the main event.

Historic evidence of the chain of events that occurred in 1857, as well as actual instrumental records of the Parkfield earthquakes that occurred recently, are extremely important clues about the recurrence of great earthquakes in southern California. Unfortunately, they do not guarantee that this convenient chain of reasoning will be apparent before the next great earthquake. Nor can they guarantee that the San Andreas will break along the same length as last time. Conceivably, the next great event may also rupture the asperity at San Bernardino—the buffer against which the 1857 earthquake stopped—and cause fault breakage as far as the Salton Sea, adding another 150 miles to the 225 miles of the San Andreas involved in a future Fort Tejon earthquake.

Further reading

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Seismologists Should Support Their International Association

*By Bruce A. Bolt,
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In the last two decades, the number of seismologists has greatly increased throughout the world. Many new professionals are not aware of the history of their own international association, the International Association of Seismology and Physics of the Earth's Interior (IASPEI) nor of its present activities. This lack of information is a pity because the strength of seismology internationally depends to a considerable extent on the work of the IASPEI.

The history of the IASPEI has been written recently by Professor J. P. Rothé (1981). His account is extraordinarily interesting because it covers a period (1901-51) when seismology was forming as a science and when some of its greatest practitioners were engaged in the study of earthquakes and seismic waves. Rothé's paper has a brief appendix by R. D. Adams, the present Secretary-General, who brings the history of the IASPEI up to 1980. It is of interest that a key motivation, from the earliest discussions of a need for international cooperation in seismology, was "the utility and indeed the scientific necessity for an international system of stations for the observation of earthquakes." The original Association of Seismology (1904-16) was formed with 18 countries as members after a convention which ended with shouts of "Long live the new era of seismology!" During the First World War, the Association went into abeyance and was revived subsequently as the Seismology Section of the International Union of Geodesy and Geophysics (IUGG).

The IASPEI, as we know it today, was born with new statutes out of the IUGG at its General Assembly in Stockholm in 1930. The first meeting of the International Association of Seismology (IAS) was held in Lisbon in September 1933; 41 people were present. Important topics being discussed by the IASPEI at that time were standard notation, adoption of standard

traveltime curves, and the need for earthquake catalogs to be set up with the help of punched-card sorters (the ancestor of digital computers).

With the outbreak of the Second World War, the dislocation of the IASPEI was again repeated, so that after the war it had to be reorganized, largely through the efforts of R. Stoneley and J. P. Rothé. At the Assembly held in Brussels in 1951, the historical step was taken to include in the IASPEI the study of physics of the Earth's interior; thus, IASPEI was born.

The main activity of the IASPEI is to hold assemblies every 4 years with the IUGG. These have been held in Rome, Toronto, Helsinki, Berkeley, Zurich, Moscow, Grenoble, and Canberra. Every 2 years, a separate assembly is held which has included Madrid (1969), Lima (1973), Durham, England (1977), and London, Ontario (1981, in connection with the International Association for Earthquake Engineering.) Over 400 registered participants attended the last assembly. Some assemblies have been noted for announcements of great scientific importance; at the 1957 Toronto Assembly, information was released for the first time on source details of a nuclear explosion (in Nevada); at the 1960 Helsinki meeting, several seismologists dramatically announced the unequivocal observations of free oscillations of the Earth following the great Chilean earthquake of May 1960.

A full program has been planned for the 18th General Assembly of the IUGG at Hamburg, Federal Republic of Germany, for August 15 to 27, 1983. Not only has IASPEI helped select the general IUGG symposia, but it has nominated coconvenors in relevant cases. A specific IASPEI program of technical sessions, commission meetings, and business sessions has been arranged. Many of these fill gaps not covered by the general IUGG symposia. There will be two special lectures, one by G. J. Wasserburg on "Inferences of Mantle Structure and Evolution from Isotopic Geochemistry" and one by B. L. N. Kennett on "Inverse Problems in Perspective."

The IASPEI also carries out vital activities between assemblies, most of which are organized through its commissions. At the present time, there are commissions on control source seismology, digital seismology, earthquake prediction, heat flow, microseisms, physical properties of the material of the Earth's interior, quantitative geodynamics, strong-motion seismology, and practice. The last is a central commission dealing with standards and procedures especially associated with earthquake observations. There also has been a Standard Earth Model Committee, and, not least, there is the large and growing



The Bureau of the International Association of Seismology and Physics of the Earth's Interior (IASPEI) at a meeting at Newbury, England, in March 1982. From left, R. D. Adams, Secretary-General; B. A. Bolt, President; Ziro Suzuki, Second Vice-President; and V. I. Keilis-Borok, First Vice-President.

European Seismological Commission which operates more or less independently. In recent years, the Commission on Control Source Seismology had a productive workshop (Utah, August 1980) to assess source techniques; in May 1982, a special IASPEI workshop was held at Suzdal, U.S.S.R., on the theory, observation, and causes of seismic anisotropy. In September 1982, a joint United Nations Educational, Scientific, and Cultural Organization (UNESCO)/IASPEI symposium on seismicity and prediction will occur in Beijing, People's Republic of China. On a somewhat larger scale, an extraordinary regional assembly is planned late in 1984 in India in cooperation with Indian seismologists and geophysicists. The following year will be the 1985 IASPEI Assembly in Japan—the first meeting of our Association, strangely enough, to be held in that seismically and seismologically active country.

In recent years, the IASPEI has endeavored to influence international programs dealing with broad seismological questions such as seismic risk and the copying of crucial historical records of great earthquakes. In this work, the Bureau of IASPEI has worked closely with UNESCO to propose grants of funds to support these activities. Thus, at the 1981 London, Ontario, Assembly, working groups supported by UNESCO met on both copying historical seismograms and the selection of international experimental sites for earthquake prediction research. This cooperation with UNESCO and other international agencies is in the interest of all seismologists because it reduces funding overlaps and funnels activities through the IASPEI with its long scientific tradition.

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Cooperative Seismology Studies Between the U.S. and the People's Republic of China

The U.S. Geological Survey began to evolve a cooperative research program with its counterpart in the People's Republic of China (China) when former Director H. William Menard, as a member of a U.S. Government delegation of senior science administrators, visited Beijing in June 1978, and a Science and Technological Cooperation Agreement was signed on January 31, 1979.

Three requirements must be met in Survey activities planned to be undertaken in cooperation with China:

- The work done must show a clear benefit to the United States.
- The work done must strengthen our ability to achieve the objectives of our domestic programs and not represent a diversion of resources for them.
- The exchanges must be financed from funds currently available.

Three types of activities are being undertaken with China:

- Joint projects to be accomplished under the umbrella Science and Technology Agreement between the United States and China.
- Coordination and review of disciplinary areas for mutually beneficial cooperative research programs.
- Exchange of visiting scholars (carried out under the umbrella Science and Technology Agreement) between the United States and China.

Earthquake Studies

Earthquake studies are the most thoroughly developed part of the research program with China. The participating scientists from both countries are

experts in seismological instrumentation and field operations, seismological data analysis and interpretation, and other investigations relevant to earthquake prediction.

Benefits to the United States from these cooperative earthquake studies are two. First, field operations in China allow the Survey to observe at first hand the effects of large damaging earthquakes and to acquire a large body of information that will augment observations of earthquake damage in the United States. The second advantage offered by cooperation with the Chinese is access to a large and successful earthquake prediction program. China has a very active earthquake prediction program because of the high number of damaging earthquakes and the consequent great losses of life and property that occur in that country. The most notable of several predicted earthquakes in China was the Haicheng event of 1975; that prediction caused officials to order the city evacuated, saving many thousands of lives.

Because of the widespread and frequent earthquake damage in China, the Chinese have devoted a large amount of manpower and much effort to gathering and examining data for earthquake premonitors. The Chinese have compiled a very complete 2,000-year history of seismicity in China, and these historical records plus the current data base are unmatched in the world. The Survey will have access to this information, and the Chinese prediction program allows the Survey to evaluate China's methods, analysis techniques, and prediction successes and failures. The results of this effort are directly applicable to predicting earthquakes in the United States. A brief description of the major components of the earthquake program follows:

Premonitory phenomena and techniques for earthquake prediction

The Survey makes field observations of earthquake precursors and analyzes the observations. The work is concentrated on areas near Beijing and in Western Yunnan Province. Current activities are as follows:

- *Beijing seismic network support.*—Several Chinese scientists are to be trained in the United States in the operation of the network system and in the use of special routines and techniques used by the Survey.

- *Magnetic precursors.*—Measurement of precursory changes in the geomagnetic field in seismic areas near Beijing and in western Yunnan Province began with Survey field work in the fall of 1980. Recording magnetometers will be shipped to China, and a Survey delegation returned to Yunnan in late 1981 to resurvey the magnetic network and discuss Chinese measurements made over the past year.
- *Deformation observations.*—Survey observations of crustal deformation near active faults began in 1981. A laser distance meter will be used in China for increased surveillance of motion on active faults.
- *Seismic observations.*—A Survey delegation discussed the installation of additional seismometers in the existing Chinese network in Yunnan Province in 1980. Agreement was reached on the type of instrument, and six systems have been ordered.
- *Analysis of strain data.*—Chinese and U.S. university scientists, the latter supported by the Survey and the National Academy of Science, analyzed strain data from Chinese observatories. Analysis techniques were developed to permit removal of background "noise" from strain records, and strain events apparently precursory to the disastrous Tangshan earthquake were identified.
- *Haicheng earthquake analysis.*—The Survey is supporting a cooperative effort with Chinese scientists to analyze foreshocks and aftershocks of the Haicheng earthquake of 1975. This event was predicted, and Haicheng evacuated, due to unusual foreshock activity. Analysis of these events and following aftershocks suggested that different faults were involved in the foreshock sequence than in the main shock and aftershocks.

EARTHQUAKES

January-February 1982

By Waverly J. Person,
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A number of significant earthquakes occurred in many parts of the world during the first month of this year. The first major earthquake (magnitude 7.0-7.9) of the year was on January 11 in the Philippine Islands. The second major quake, on January 18 in the Aegean Sea, was followed by several other earthquakes which caused injuries or damage in other parts of the world.

In the United States, a number of earthquakes occurred, but only minor damage was reported. Arkansas experienced a swarm of earthquakes beginning on January 12. Canada experienced one of its strongest earthquakes in a number of years on January 9; this earthquake caused slight damage in Maine.

Tennessee

The south-central part of this State experienced a small earthquake on January 1 at 8:00 p.m. CST. The magnitude 2.9 tremor was located about 6 miles south of Lynchburg. Intensity effects, which register V on the Modified Mercalli Intensity Scale (MM), were noted at Lynchburg, and MM IV effects were experienced at Fayetteville, Flintville, Huntland, and Mulberry. The quake was felt in other areas of Franklin, Lincoln, Moore, and Marshall Counties.

Texas

The southwestern part of this State experienced a small, but rare, earthquake on January 4 at 10:56 a.m. CST. The magnitude 3.8 earthquake was located about 31 miles northeast of Fort Stockton and was felt in the Fort Stockton area.

Utah

On January 7 at 9:22 a.m. MST, a very small earthquake was located in the southwestern part of this State near the Arizona border. The magnitude 2.9 tremor was located about 18.6 miles west of Kanab and was felt at Colorado City, Arizona.

Canada

The southeastern part of this country was shaken by a moderate earthquake on January 9 at 7:54 a.m. EST. The magnitude 5.7 earthquake was located in New Brunswick about 62 miles north of Fredericton and 62 miles east of Presque Isle, Maine. Slight damage was experienced at Bridgewater, Caribou, Easton, Haynesville, Monticello, Presque Isle, Oakfield, and Stockholm, Maine. The quake was felt in the Maritime Provinces and parts of Quebec in Canada and throughout much of New England and into the New York City area (MM VI.) This quake was followed by a number of aftershocks; the largest were a magnitude 5.1 about 3 hours and 43 minutes after the main shock and a magnitude 5.5 on January 11 at 4:41 p.m. EST. Again, these quakes were felt in the Maritime Provinces and throughout much of New England. There were no reports of damage.

Philippine Islands

Luzon Island was struck by a major earthquake on January 11. The magnitude 7.0 earthquake was located about 236 miles southeast of Manila. Several people were injured, and some damage occurred at Virac

(MM IV). MM V effects were experienced at Catbalogan, Legaspi, and Manila. The quake was felt throughout the central Philippines from Baguio and Roxas.

Honduras

The southern part of this country experienced a strong earthquake on January 11 at 11:48 p.m. local time. The magnitude 6.0 earthquake was centered about 62 miles south of Tegucigalpa near the Nicaraguan border. Two people were injured, and there was moderate damage at Amapala. There was slight damage at Masaya, Nicaragua, and the quake was felt strongly in much of southern Honduras and western Nicaragua.

Aegean Sea

A major earthquake occurred in the Aegean Sea on January 18 over 136 miles northeast of Athens. The magnitude 7.0 earthquake was felt strongly throughout Greece; it was also felt in Bulgaria, southeastern Italy, southeastern Yugoslavia, and western Turkey. There were no reports on damage. This same area experienced a magnitude 7.2 earthquake on December 19, 1981, which caused some damage. (See *Earthquake Information Bulletin*, vol. 14, no. 3, p. 119.)

Arkansas

The north-central part of this State experienced an unusual series of earthquakes beginning on January 12 and continuing into February; more than 4,000 earthquakes occurred with magnitudes between 2.0 and 4.5, as well as many smaller quakes. The quakes were located near Enola about 31 miles north of Little Rock.

The largest of the series was a magnitude 4.5 shock on January 20 at 6:34 p.m. CST; MM IV effects were noted at Rose Bud and Ward. This earthquake was felt throughout north-central Arkansas including Conway, Little Rock, Malvern, Heber Springs, and Searcy. It was also felt at Robinsonville, Mississippi, and in several areas of southern Missouri.

The second largest quake in the area was of magnitude 4.3 on January 22 at 9:23 p.m.

CST. MM V effects were noted at Enola, Rose Bud, and Vilonia. This quake was felt throughout much of north-central Arkansas. On February 24 at 1:27 p.m. CDT, a magnitude 3.9 earthquake occurred, and MM V effects were noted at Enola, and MM IV effects, at Mt. Vernon. The quake was also felt at Conway and Greenbrier.

On February 28 at 6:12 p.m. CST, the same area was shaken by a magnitude 4.3 quake; MM V effects were experienced at Vilonia, and MM IV effects, at Enola, Mt. Vernon, and Rose Bud. The quakes were also felt in the areas of Alco, Conway, Fox, Greenbrier, and Weldon. No damage was reported from any of the earthquakes.

On February 2 at 3:27 a.m. CST, the northeastern part of the State experienced a minor earthquake. The magnitude 3.4 quake was located in Mississippi County about 6 miles west of Blytheville near the Missouri border. MM IV effects were reported at Dell, Arkansas and Hornersville, Missouri. It was also felt at Burdette, Luxora, and Manila, Arkansas.

Northern New England

This area was shaken by a sharp earthquake on January 18 at 7:15 p.m. EST. The magnitude 4.5 earthquake was located in New Hampshire about 6 miles southwest of Laconia. Slight damage was experienced at Bristol, Laconia, Canaan, and Danbury, New Hampshire, and North Hartland and White River Junction, Vermont. The shock was felt throughout most of New England, northeastern New York, and into southern Quebec and northeastern Ontario (MM VI). Some aftershocks occurred; the largest was a magnitude 2.8 quake on January 27 at 10:43 a.m. EST. MM V effects were experienced at Center Harbor, Bristol, Laconia, and Lochmere, New Hampshire. The quake was felt in other areas of Carroll and Belknap Counties and also in parts of Grafton, Hillsborough, Merrimack, Strafford, and Sullivan Counties.

Great Nicobar Islands

On January 20 a magnitude 6.3 earthquake occurred in the vicinity of the Great Nicobar Islands. Some people were injured,

and the quake caused considerable damage in the area. This shock was followed by one of magnitude 6.2 about 2 hours and 44 minutes later which caused additional damage. A number of smaller earthquakes occurred, but no additional damage was reported.

Windward Islands

A magnitude 5.2 earthquake struck this group of islands on January 20 at 11:16 a.m. local time. It was centered about 31 miles east of St. Lucia. On St. Lucia, six people were injured when they jumped from a building.

Hawaii

A number of earthquakes occurred in this vicinity during this reporting period. The largest were on January 21 at 11:53 a.m. HST and at 12:29 p.m. HST. Both earthquakes were of magnitude 5.5 and were located on the southern part of the big island about 9 miles west of Pahala. Minor damage was experienced in the areas of Pahala, Naalehu, and Kau. The earthquakes were felt throughout the big islands and on Maui, Molokai, and Oahu. A number of aftershocks have followed, four of which had magnitudes of 4.0 or greater. Two aftershocks occurred at 1:01 p.m. HST and 1:37 p.m. HST, less than 2 hours after the main shock, and had magnitudes of 4.4 and 4.3, respectively. The largest of the aftershocks was on January 22 at 5:45 p.m. HST. On February 2 at 6:30 a.m. HST, a magnitude 4.4 earthquake struck. These earthquakes were felt, but there were no additional reports of damage.

California

A number of earthquakes occurred in California during this reporting period, but most had magnitudes of less than 4.0. The first quake that had a magnitude of 4.0 or greater was on January 24 at 7:44 a.m. PST. This shock had a magnitude of 4.1 and was located about 31 miles east of Bishop near the Nevada border. MM III effects were noted at Bishop, California, and Dyer, Nevada.

The largest earthquake to affect the State was on February 6 at 4:02 a.m. PST. The magnitude 5.3 earthquake was centered about 68 miles northwest of Eureka. MM IV effects were experienced at Eureka and Ferndale. It was also felt in the areas of Crescent City, Miranda, Rio Dell, and Trinidad.

On February 18 at 8:53 p.m. PST, the northeastern part of the State was shaken by a light earthquake. The magnitude 4.0 earthquake was located about 48 miles north of Soda Springs in the Quincy area. MM V effects were experienced at Quincy and Spring Garden. It was also felt in the areas of Greenville, Taylorsville, and Vinton.

The northeastern part of the State experienced a magnitude 4.1 earthquake on February 23 at 9:23 p.m. PST. This quake was located near the coast about 34 miles west of Eureka and was felt at Eureka and McKinleyville (MM IV).

Again on February 28 at 12:18 p.m. PST, the northern part of California was shaken by a light earthquake. The magnitude 4.0 quake was located about 31 miles south of Ukiah and was felt in Lake and Sonoma Counties.

Aleutian Islands

The Fox Islands, part of the Aleutian island chain, experienced a strong earthquake on January 24 at 6:30 p.m. BST. The magnitude 6.0 earthquake was centered about 43 miles south of Dutch Harbor. MM IV effects were noted at Cold Bay. It was also felt at Dutch Harbor and Unalaska.

Southern New England

The southern part of Massachusetts experienced a minor earthquake on January 27 at 1:50 p.m. EST. The magnitude 3.0 quake was located about 31 miles south of Boston. MM III effects were experienced in the areas of Brant Rock, Cataumet, and Middleboro. The quake was also felt at Raynham.

California-Nevada Border Region

This area experienced a series of earthquakes on January 28. The first, at 2:51 p.m.

PST, had a magnitude of 3.9 and was followed by two larger earthquakes. The first of these, which occurred about 1 minute later, had a magnitude of 4.2, and the second, which occurred about 77 seconds later, had a magnitude of 4.8. These quakes were located about 6 miles north of Luning, Nevada. MM V effects were experienced at Luning, and MM IV effects, at Mina and Hawthorne, Nevada.

Java

The western part of Java experienced a damaging earthquake on February 10. The magnitude 5.5 quake was centered about 62 miles south of Jakarta in the vicinity of Sukabumi. Several people were injured, and over 700 homes, schools, and government buildings were damaged in Sukabumi.

Montana

The capital of this State, Helena, experienced a very minor earthquake on February 20 at 2:09 a.m. MST. The magnitude 2.6 tremor was located in the vicinity of Helena and was felt in that area.

On February 22 at 3:44 a.m. MST, the northwestern part of the State experienced a minor earthquake. The magnitude 3.1 quake was located about 12.8 miles east of

Kalispell. MM IV effects were experienced at Big Fork, and MM III effects, at Big Arm. The quake was also felt at Creston.

U.S. Activity*

Alaska	7
Arizona	2
Arkansas**	9
California	18
Connecticut	3
Hawaii	21
Idaho	1
Maine	4
Massachusetts	4
Mississippi	1
Missouri	1
Montana	2
Nevada	4
New Hampshire	6
New York	2
Tennessee	1
Texas	1
Utah	1
Vermont	4
Total	92

*Felt earthquakes as reported from many sources.

**Exclusive of the swarm of earthquakes in the State.

**Preliminary Locations
January-February 1982**

Date	Origin time	Region	Coordinates		Depth (km)	Magnitude
			Latitude	Longitude		
Jan. 2-----02	00	25.7 Tennessee-----	35.2 N	86.4 W	7	12.9 m _b Lg
Jan. 4-----16	56	08.2 West Texas-----	31.1 N	102.5 W	10	3.8 m _b Lg
Jan. 7-----16	21	46.4 Utah-----	37.0 N	112.9 W	8	12.9 M _L
Jan. 9-----12	53	51.8 New Brunswick-----	47.0 N	66.7 W	10	5.7 m _b
Jan. 11-----16	36	42.9 -----do-----	47.0 N	66.8 W	6	5.1 m _b
Jan. 11-----06	10	04.0 Luzon, Philippine Islands.	13.7 N	124.3 E	26	17.0 M _S
Jan. 12-----21	41	07.9 New Brunswick-----	47.0 N	66.7 W	7	5.5 m _b Lg
Jan. 12-----05	48	17.2 Honduras-----	13.2 N	87.6 W	4	6.0 M _S
Jan. 18-----19	27	24.3 Aegean Sea-----	40.0 N	24.3 E	10	6.9 M _S
Jan. 19-----00	14	42.0 Northern New England.	43.5 N	71.6 W	8	4.5 m _b Lg
Jan. 20-----04	25	12.7 Nicobar Islands region.	6.9 N	94.0 E	28	6.3 M _S
Jan. 21-----07	09	18.8 -----do-----	7.1 N	94.0 E	39	6.2 M _S
Jan. 21-----15	15	47.7 Windward Islands.	13.7 N	60.4 W	70	5.2 M _b
Jan. 21-----00	33	54.8 Arkansas-----	35.2 N	92.2 W	3	4.5 m _b Lg
Jan. 21-----21	52	41.0 Hawaii-----	19.2 N	155.6 W	10	5.5 m _b
Jan. 21-----22	29	13.0 -----do-----	19.2 N	155.6 W	13	5.5 m _b
Jan. 21-----23	01	09.7 -----do-----	19.2 N	155.6 W	10	4.4 M _L
Jan. 21-----23	37	17.4 -----do-----	19.2 N	155.6 W	12	4.3 M _L
Jan. 23-----03	45	08.1 -----do-----	19.2 N	155.6 W	10	4.6 M _L
Jan. 24-----03	22	44.4 Arkansas-----	35.2 N	92.2 W	0	4.3 m _b Lg
Jan. 24-----15	44	07.6 California-Nevada border region.	37.5 N	117.8 W	5	4.1 M _L
Jan. 25-----05	29	33.5 Fox Islands, Aleutian Islands.	53.3 N	165.8 W	58	6.0 m _b
Jan. 27-----16	43	14.6 Northern New England.	43.5 N	71.6 W	2	2.8 m _b Lg
Jan. 27-----18	50	05.1 Southern New England.	41.9 N	71.0 W	2	3.0 m _b Lg
Jan. 28-----22	50	44.9 California-Nevada border region.	38.6 N	118.2 W	5	3.9 M _L
Feb. 2-----09	26	46.3 Arkansas-----	35.9 N	90.1 W	10	3.4 m _b Lg
Feb. 2-----16	29	49.9 Hawaii-----	19.2 N	155.6 W	11	4.4 M _L
Feb. 6-----12	01	58.5 Off coast of northern California.	41.1 N	125.4 W	5	5.3 M _L
Feb. 10-----16	17	50.4 Java-----	7.0 N	106.9 E	33	5.5 m _b
Feb. 19-----04	53	15.7 Northern California.	39.9 N	120.7 W	5	4.0 M _L
Feb. 20-----09	08	49.5 Montana-----	46.6 N	112.1 W	5	2.7 M _L
Feb. 22-----10	43	51.7 -----do-----	48.2 N	113.9 W	5	3.1 M _L
Feb. 24-----05	22	42.0 Near coast of northern California.	40.7 N	124.9 W	5	4.1 M _L
Feb. 28-----19	27	14.6 Arkansas-----	35.2 N	92.2 W	2	3.9 m _b Lg
Feb. 28-----20	17	51.8 Northern California.	38.8 N	122.8 W	4	4.0 M _L
Mar. 1-----00	12	10.0 Arkansas-----	35.2 N	92.2 W	7	4.3 m _b Lg

*Magnitude from Love waves.
*Richter magnitude.

*Magnitude from body waves.
*Magnitude from surface waves.

Announcements

Meeting

Meeting of the World Organization of Volcano Observatories, Reykjavik, Iceland

From August 15 to 22, 1982, representatives of volcano observatories and other research institutions will meet to strengthen the ties between scientists involved in monitoring volcanoes. An assessment will be made of the observation network's equipment and instrumentation.

For further information, contact:

Gudmundur Sigvaldason,
Nordic Volcanological Institute,
University of Iceland,
Reykjavik, Iceland.

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Professional Papers

P 1141. Research in the Geysers—Clear Lake Geothermal Area, Northern California. Edited by R. J. McLaughlin and J. M. Donnelly-Nolan. 1981. 259 p. \$9.

This compendium presents a cross section of current research in the Clear Lake region. The area is the site of The Geysers steam field and geothermal power development and of the Clear Lake Volcanics, the youngest rocks of which are only 10,000 years old. Stratigraphic, petrologic, geophysical, geochemical, and paleontologic studies are represented that show both the state of today's research and some directions for future work.

P 1240-B. Facing Geologic and Hydrologic Hazards—Earth-Science Considerations. Edited by W. W. Hays. 1981. p. B1-B108. \$7.50.

Earth science information is assembled to answer some of the broader questions about earthquakes, floods, ground failures, and volcanic eruptions. Actions to reduce losses are suggested for planners and decisionmakers. The first of this series of Earth-Science Special Reports, *Synthetic Fuels Development—Earth-Science Considerations*, was published in 1979 and was not identified as part of the U.S. Geological Survey Professional Paper series. When the earlier report is reprinted, it will be designated as U.S. Geological Survey Professional Paper 1240-A. Subsequent reports in the Earth-Science Special Report series will be designated as lettered chapters in Professional Paper 1240.

P 1250. The 1980 Eruptions of Mount St. Helens, Washington. Edited by P. W. Lipman and D. R. Mullineaux. 1981 (1982). 844 p.; 1 plate in pocket. \$35.

The reawakening of Mount St. Helens Volcano in March 1980 and its catastrophic eruption of May 18 surely will rank among the most significant geological events in the United States in the

Circulars (free)

C 0853-B. Earthquakes in the United States, April-June 1980. By C. W. Stover, J. H. Minsch, P. K. Smith, and W. J. Person. 1981. p. B1-B53.

C 0853-C. Earthquakes in the United States July-September 1980. By J. H. Minsch, C. W. Stover, B. G. Reagor, and P. K. Smith. 1981. p. C1-C42.

C 0854-A. Seismic Engineering Program Report January-April 1980. 21 p.

This issue contains a summary of the accelerograms recovered from the U.S. Geological Survey National Strong-Motion Network during the period January 1-April 30, 1980. Also included are reproductions of some of the significant accelerograms from the Livermore Valley earthquakes of January 24 and 26 and the southern California (Horse Canyon) earthquake of February 25, summaries of recent strong-motion reports, notes on the availability of digitized data, and additional general information pertinent to the Survey and to other strong-motion programs.

Miscellaneous Field Studies (MF) Maps

MF-709. Maps Showing Maximum Earthquake Intensity Predicted in the Southern San Francisco Bay Region, California, for Large Earthquakes on the San Andreas and Hayward Faults. By R. D. Borcherdt, J. F. Gibbs, and K. R. Lajole. 1975.

Three sheets. Lat 37° to 37°52'30", long about 121°30' to 122°37'30". Scale 1:125,000 (1 inch = about 2 miles). Sheet 1, 25 by 32 inches; sheets 2 and 3, 39 by 39 inches. \$2.25 per set. (Reprint.)

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Map 1, Map of the Crodine fault and Renn scarp, Houston metropolitan area, Texas, lat about 29°40' to about 29°42'30", long about 95°37'30" to 95°45'. Map 2, map of the Long Point, Piney Point East, Piney Point West, Eureka Heights, Memorial Park, and western part of Pecore West faults, Houston metropolitan area, Texas, lat 29°40' to about 29°, long about 95°22'30" to about 95°37'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 43 by 57 inches. 75¢. (Reprint.)

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(I) Series

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Geophysical Investigations Maps

GP-0932. *Map Showing Aeromagnetic Anomalies, Faults, Earthquake Epicenters, and Igneous Rocks in the Southern San Francisco Bay Region, Calif.* By E. E. Brabb and W. F. Hanna. 1981.

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Preliminary Determination of Epicenters

Preliminary Determination of Epicenters. Monthly listing for September 1981. 23 p.

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80-778. *An Evaluation of the Effects of the October 31, 1895, Charleston, Missouri, Earthquake.* By M. G. Hooper and S. T. Algermissen. 44 p., 1 over-size sheet (NC, Da, M; Missouri Geol. Survey, Div. Geologic and Land Surveys (P.O. Box 250), Rolla, MO 65401.) Microfiche \$4; paper copy \$11.50.

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80-801. *Proceedings of Conference X: Earthquake Hazards Along the Wasatch and Sierra-Nevada Frontal Fault Zones.* By J. F. Evernden, compiler. 688 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$89.25.

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80-827. *EQPLT and ZEQPLT: Interactive Computer Plotting Programs for Earthquake and Geophysical Data.* By F. W. Klein. 36 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$4.50.

80-840. *An Earthquake Catalog and Velocity Model for the USGS Peter the First Range Seismic Array, Tadzhikistan, USSR.* By Jack Pelton and Fred Fischer. 28 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$3.50.

80-898. *Stability of Toutle River Blockage; Mount St. Helens Hazard Investigations.* By T. L. Youd and R. C. Wilson. 15 p. (NC, Da, M, SF, LA, S.) Microfiche \$3.50; paper copy \$1.75.

80-902. *Review of Lake Michigan Seismic Reflection Data.* By R. J. Wold. 40 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$5.

July-August Natural Hazards Events in History

July 20, 1952	Earthquake of Intensity X [on the Modified Mercalli Intensity Scale (MM)] in Kern County, California. Caused \$60 million damage.
July 26, 1963	Skopje, Yugoslavia, earthquake of magnitude 6.0
August 12, 1929	Earthquake of MM IX near Attica, New York.
August 17, 1959	Hobgen Lake, Montana, earthquake of MM X. Huge landslide dammed a river and created "Earthquake Lake." \$11 million damage to roads alone.
August 22, 1952	Bakersfield, California, earthquake of MM VIII caused \$10 million damage.
August 23, 1953	Fallon, Nevada, earthquake of MM VIII.
August 24, A.D. 79	Eruption of Vesuvius in Italy that buried the Roman cities of Pompeii and Herculaneum.
August 27, 1883	Catastrophic eruption of Krakatoa, a volcano between Java and Sumatra. The blast was heard 3,000 miles away; the ash cloud rose to a height of 50 miles, and the fine dust caused below normal world temperatures for the next 3 years.
August 31, 1886	Charleston, South Carolina, earthquake, the greatest historical earthquake in the Eastern United States. Felt at Boston, Chicago, and St. Louis.

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Tsunami damage at Lebak, Mindanao, the Philippines, caused by the earthquake of magnitude (M_s) = 7.8 on August 16, 1976, in Moro Gulf, Mindanao.
(Photograph by Robert E. Wallace.)



UNITED STATES
DEPARTMENT
OF THE
INTERIOR
GEOLOGICAL
SURVEY

Earthquake Information Bulletin

September-October 1982, Volume 14, Number 5



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**UNITED STATES DEPARTMENT OF THE
INTERIOR**

JAMES G. WATT, Secretary

**GEOLOGICAL SURVEY
Dallas L. Peck, Director**

EARTHQUAKE INFORMATION BULLETIN is published bimonthly by the U.S. Geological Survey to provide current information on earthquakes and seismologic, volcanologic, and related activities of interest to both general and specialized readers. The Secretary of the Interior has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through June 30, 1984.

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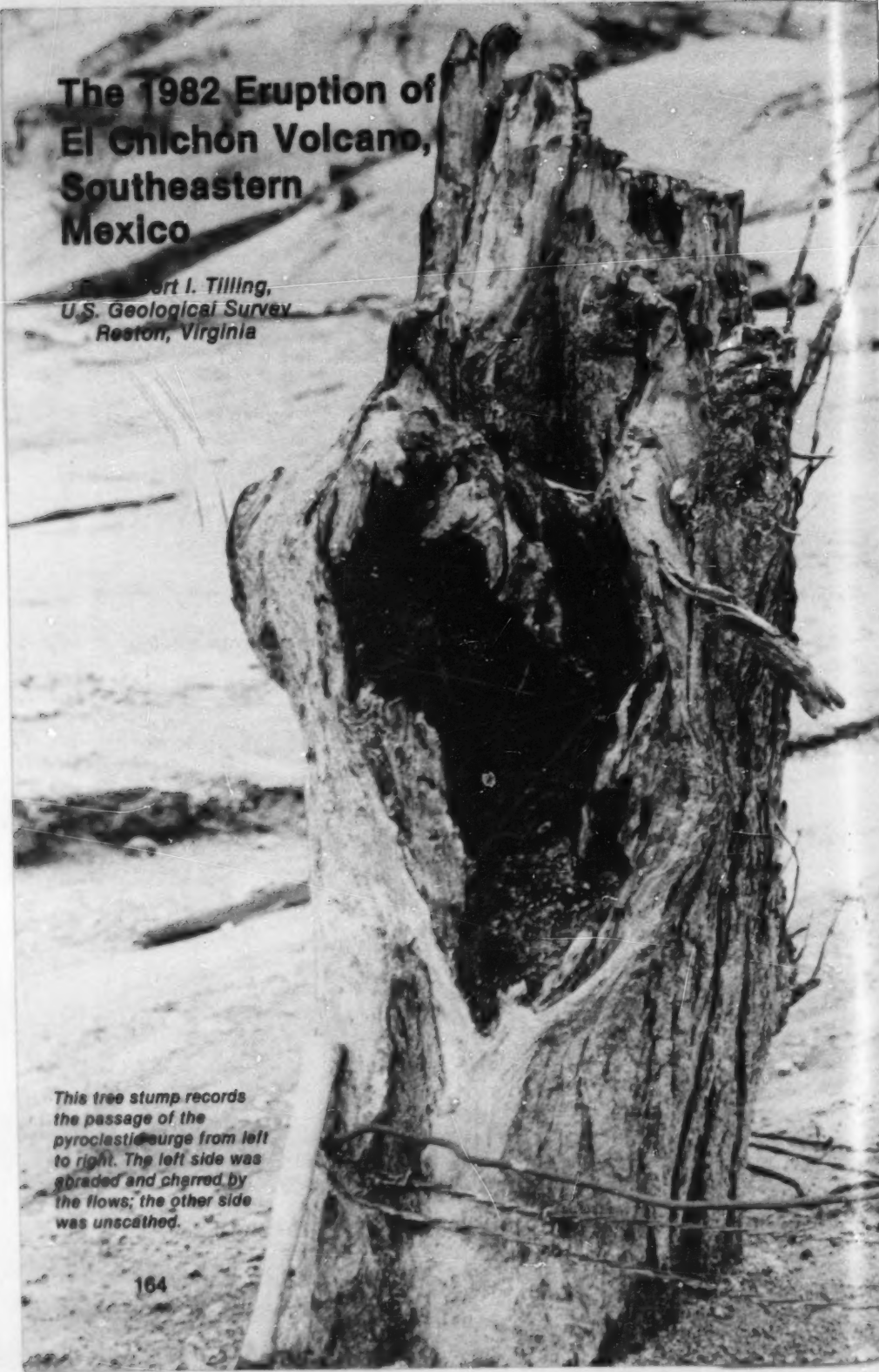


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Cover: View of the eruption of El Chichón Volcano, southeastern Mexico, on April 2, 1982. The steam and ash plume is about 12,000 feet high. The volcanic clouds from the eruptions of El Chichón are the most extensive observed worldwide for many decades. (Photograph from United Press International.)



The 1982 Eruption of El Chichón Volcano, Southeastern Mexico

**Part I. Tilling,
U.S. Geological Survey
Reston, Virginia**

*This tree stump records
the passage of the
pyroclastic surge from left
to right. The left side was
abraded and charred by
the flows; the other side
was unscathed.*

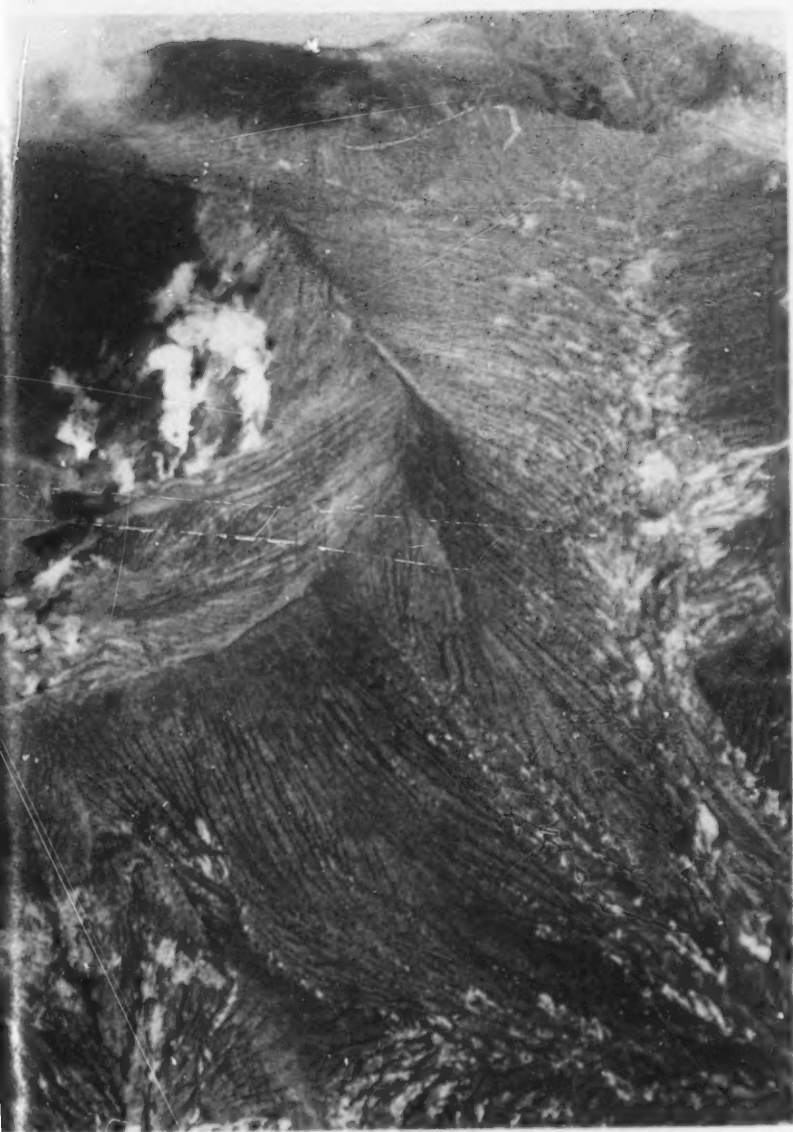
The author and Wendell A. Duffield of the U.S. Geological Survey's Menlo Park Office in California took part in an expedition to El Chichón (Chichonal Volcano) in May-June 1982 in cooperation with scientists of the Instituto de Geología, Universidad Nacional Autónoma de México, and of the Comisión Federal de Electricidad.

Compared with the more well-known Mexican volcanoes such as Popocatepetl or Parícutin, El Chichón is not very impressive. Hidden in the lush forested hills of Chiapas State in southeastern Mexico, it was only in 1933 that its volcanic origin was first documented. At that time, only solfataric activity, shown by fumaroles and thermal springs, was observed. Also, there was no good evidence of any historic eruptions, so the volcano was never considered a serious volcanic threat by scientists or by local inhabitants.

Avalanches of hot ash and debris from the April 3-4, 1982, eruptions of El Chichón obliterated the village of Francisco León, located about 3 miles from the volcano (see sketch map). In this view, reinforcement rods in remains of the concrete wall have been bent in the direction of pyroclastic flow (from right to left).







Aerial view of El Chichón from the north-west on June 2, 1982, showing the new crater formed in place of the original summit dome which was blown off during the March-April 1982 eruptions.

All this changed in 1982. Late in the evening on March 28, El Chichón roared into life with a tremendous explosion that sent a column of ash and gases 10 miles high within an hour. (Volcanologists class such an eruption of extreme violence as *Plinian*, after a description of the eruption of Vesuvius in A.D. 79 by the Roman historian Pliny the Younger). There were no immediate warning signals of the eruption of El Chichón, although increased earthquake activity had been noted for months, possibly a few years, before the explosion. Sound waves from the explosion were detected by instruments 7,000 miles away in Antarctica. Close to the volcano, heavy ashfall, which included incandescent fist-sized fragments, caused roofs to collapse and structures to burn. Several days later, on April 3, El Chichón again erupted violently for about an hour, and there was an even more violent eruption early the following morning. These explosions were more powerful and destructive than the initial March eruption.

Enormous amounts of ash and debris were expelled, and the material that fell out of the tall eruption clouds generated high-speed slurries of incandescent volcanic debris, ash, and hot gases that swept down all the valleys flanking the volcano. These pyroclastic flows, or "nubes ardentes" (glowing clouds), obliterated the village of Francisco León as well as other villages within a 4-mile radius of the volcano. In June, 2 months after the eruption, materials in these flows were still too hot to touch with the bare hand. The ash flows also dammed rivers and streams, forming lakes of scalding hot water. The failure of one such natural dam caused catastrophic floods down the Magdalena-Sayula-Grijalva River channels.

The eruptions destroyed El Chichón's original dome and replaced it with a 900-foot-deep crater 0.5 mile wide. The floor of the new crater is pocked by explosion pits filled with boiling water and mud that hiss and steam noisily. Near the top of the new crater wall, shattered remains of trees, which mark the former ground surface, protrude from the base of a 10-foot layer of compacted ash.

The ash injected into the atmosphere from the eruptions had drifted to southern Texas by April 5 and to Hawaii by April 10. The laser radar instrument at the National Oceanic and Atmospheric Administration's Mauna Loa Observatory in Hawaii detected layers of



◀View of the new crater of the volcano from its east rim. The explosion pits are filled with boiling water and mud.

Volcanologists returning to a helicopter of the State Government of Chiapas. View looking toward the decapitated dome of El Chichón. The dashed line shows the approximate volcano profile before the eruption. ▼





the volcanic cloud at several altitudes in the range of 12 to 16 miles. These concentrations were 100 times denser than those measured over Hawaii after the May 18, 1980, eruption of Mount St. Helens. Samples of aerosols at the base of the cloud over northern California taken by a National Aeronautical and Space Administration U-2 aircraft showed that it contained abundant sulfuric acid droplets and relatively few ash particles.

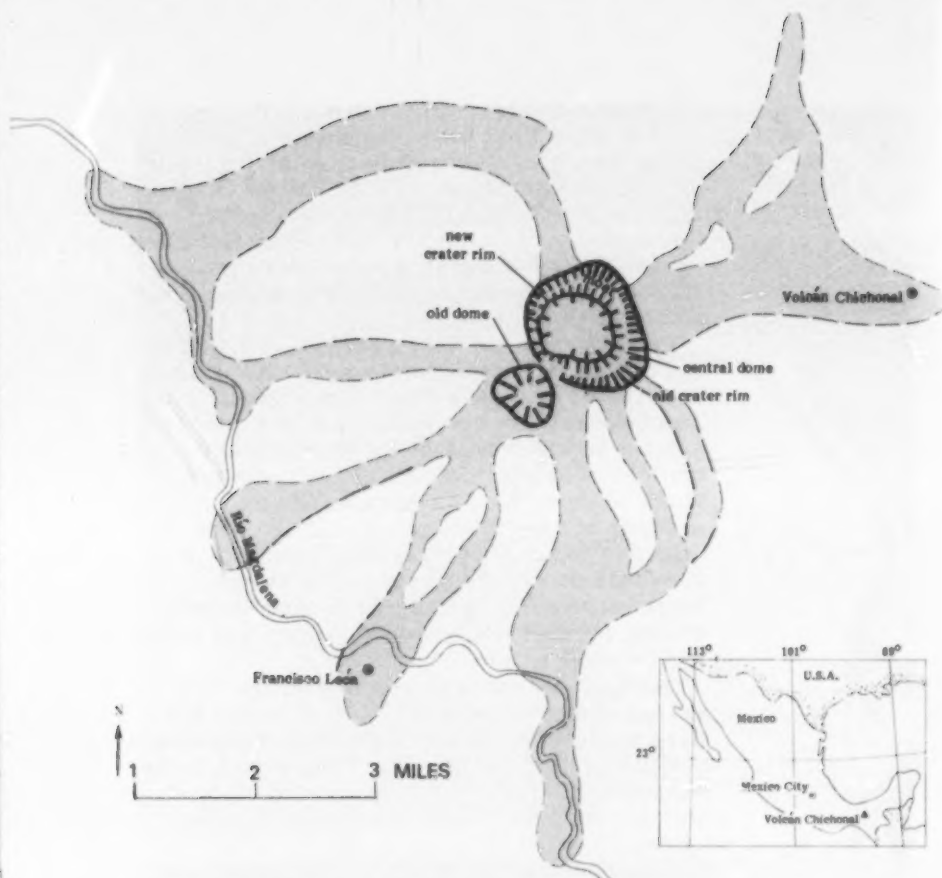
The most surprising finding was the occurrence of salt crystals, which have never been found in abundance before in volcanic clouds. The presence of salt, together with the occurrence of the mineral anhydrite (calcium sulfate) in the ash deposits, probably indicates that fragments of rock salt and anhydrite strata, which are known to exist beneath the volcano at depths of a few miles, were plucked up by the magma in its ascent to the surface. Moreover, the chemical reaction between the magma and the mineral salts would yield large amounts of carbon dioxide, sulfur dioxide, and chlorine gases that would fuel the dense eruption cloud.

Preliminary estimates suggest that the volume of ash deposited from the eruptions of El Chichón was about the same as that from the catastrophic eruption of Mount St. Helens in May 1980. Nevertheless, the atmospheric impact of El Chichón has been much greater. Among the possible reasons for this are as follows:

- Unusual atmospheric conditions that allowed maximum penetration of the stratosphere by the El Chichón aerosols;
- Anomalously high gas content of the El Chichón magma; and
- Eruption energy almost entirely upward at El Chichón, whereas there was a strong horizontal component to the blast at Mount St. Helens.

Atmospheric scientists consider that the El Chichón volcanic cloud is the largest observed in many decades. Until it becomes dispersed, the amount of ash from the eruption may reduce the amount of sunlight that reaches the Earth's surface by as much as 20 percent, which may temporarily lower global

◀ *View of the eruption of El Chichón Volcano on April 2, 1982. The steam and ash plume is about 12,000 feet high. (Photograph by United Press International.)*



Sketch map showing the location of El Chichón Volcano and the approximate locations of the major pyroclastic flows during the April 3-4, 1982, eruptions.

average temperatures by as much as 1 or 2 degrees Fahrenheit. A dramatic example of eruption-related climate change is given by the 1815 eruption of Tambora (Indonesia), which resulted in an abnormally cold summer in Northern Europe and the Eastern United States in 1816 ("the year without a summer").

Since April, El Chichón has remained relatively calm with occasional small steam-blast eruptions. The probability for another major eruption is low, although, by analogy with other stratovolcanoes, activity could continue for months, possibly years. This will likely include the extrusion of domes of viscous lava into the new crater. This has happened in El Chichón's past and will undoubtedly occur in the future as the volcano heals itself.

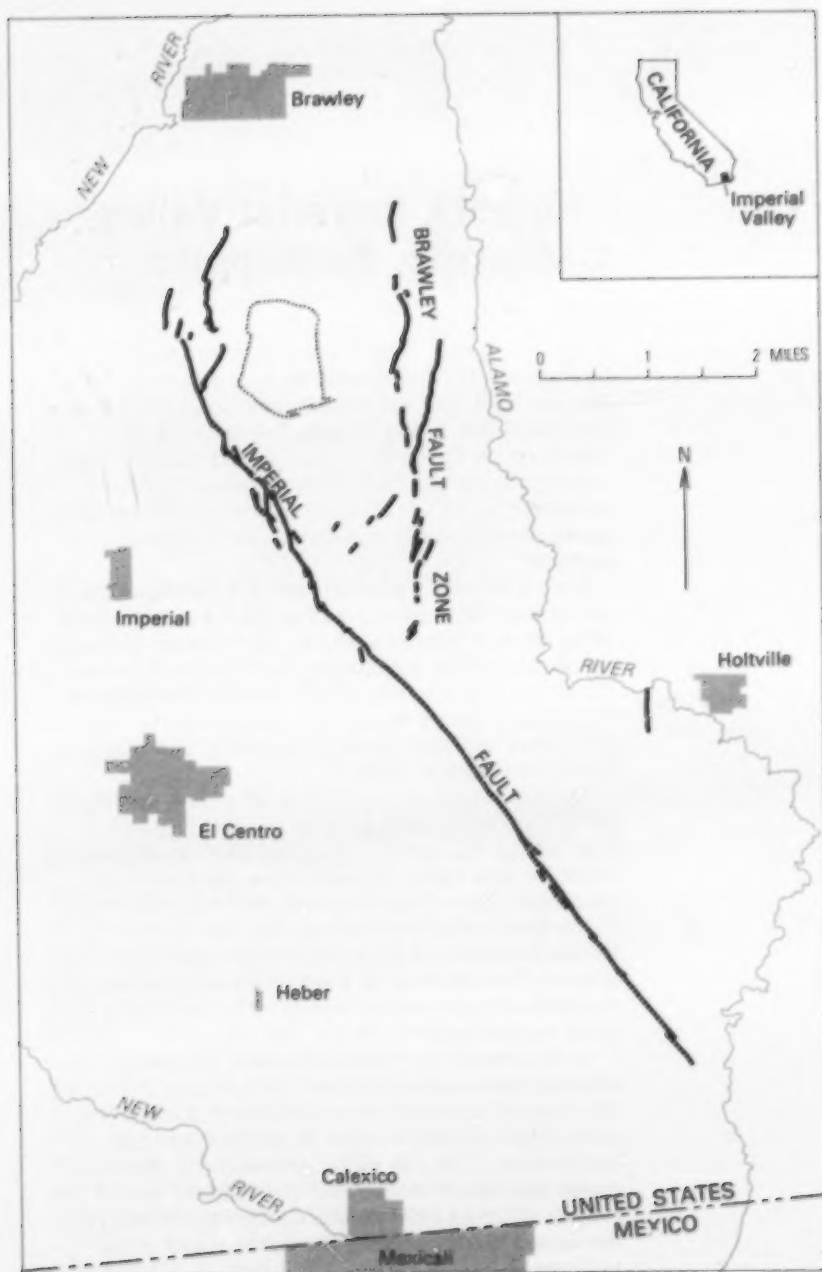
The 1979 Imperial Valley, California, Earthquake

On October 15, 1979, the largest earthquake in California in the last quarter century occurred on the Imperial fault near the international boundary between the United States and Mexico. The earthquake measured 6.6 on the Richter scale and was felt from Las Vegas, Nevada, to northern Mexico. Surface movement on four fault zones accompanied the earthquake and caused approximately \$30 million in damage.

From a scientific point of view, the earthquake was unprecedented. It generated the most comprehensive set of data on ground shaking and structural response yet recorded from a damaging earthquake anywhere in the world. It is also the first damaging earthquake in California's history for which the actual surface rupture zones had been defined by careful fault mapping prior to the seismic event.

The earthquake and its aftershocks were distributed along the Imperial and Brawley faults (fig. 1) which form part of the tectonic boundary between the North American and Pacific crustal plates. As the Pacific plate drifts slowly northwestward with respect to the North American plate, some of the crustal strain is released suddenly during moderately large earthquakes. The remaining strain is released gradually in the form of fault creep, which is often associated with small earthquakes.

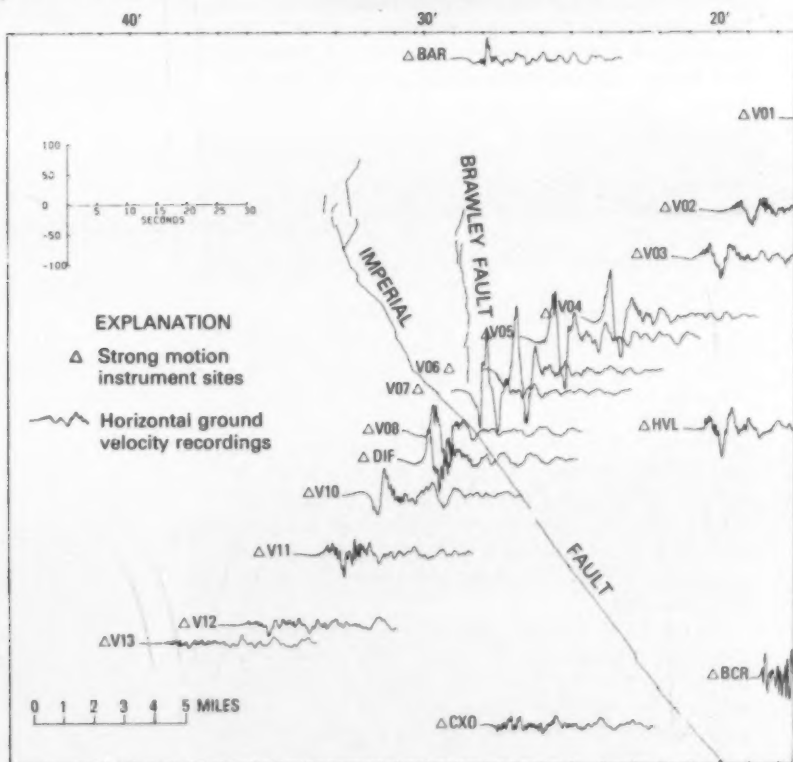
In the case of the 1979 earthquake, the ground surface ruptured suddenly along a 19.3-mile segment of the Imperial fault, with additional surface movement along approximately 8 miles of the Brawley fault, as shown in figure 1. The maximum horizontal displacements reached 31 inches near the southern end of the rupture (10 miles from the main-shock epicenter) and decreased to 0.6 inch near the northern end of the fault (fig. 2).



◀ Figure 1.—Heavy black line shows the location of surface ruptures that occurred during the 1979 Imperial Valley earthquake.

Figure 2.—Strike slip offset of 23 inches on a canal on the Imperial Valley fault; the concrete patch had already been cracked by postearthquake slip.

Figure 3.—Recordings of horizontal ground velocity from the U.S. Geological Survey ground-motion array at El Centro, California, and four other strong motion accelerograph sites in the Imperial Valley.



Because of the frequent occurrence of seismic activity in the region and the possibility of a repeat of the magnitude 7.1 Imperial Valley earthquake of May 18, 1940, the region has been under intensive study by scientists and engineers from the U.S. Geological Survey and other research institutions. In anticipation of strong earthquakes in the areas, Survey engineers had devoted considerable attention to the design and installation of comprehensive accelerograph networks capable of recording strong shaking in the ground and in buildings and other structures. Such data are essential for establishing engineering design criteria for structures in seismically active areas.

When the 1979 Imperial Valley earthquake occurred, significant ground-motion and structural response records were obtained from 32 sites [4 of which are maintained by the California Division of Mines and Geology (CDMG)] located near the surface rupture zone. In addition, ground-motion data were also obtained from nine stations in Mexico installed under a cooperative program by the University of California, San Diego, and the National University of Mexico, Mexico City. The records from both countries are of considerable interest in the scientific and earthquake-engineering research community because they provide new and highly important information on ground motion and the response of structures.

The El Centro, California, ground-motion array, a 13-accelerograph, 28-mile-long array oriented perpendicular to and crossing the Imperial fault near El Centro, obtained data of particular interest. Strong-motion data from this array (fig. 3) show that the horizontal velocity of the ground decreased with distance from the fault trace and that the velocity of ground shaking was greatest toward the northern end of the fault. In-depth studies of the data also indicate that the Earth's crust started to slip at a depth of about 5 miles below the surface east of Calexico, Baja California, Mexico, with the rupture breaking the surface 6 miles northwest of the epicenter and then continuing to the northwest along the fault to an area near Brawley.

As the Earth's crust ruptured in a northwestward direction, it generated at station VO6, which is within 0.6 mile of the fault trace, the largest amplitude of shaking yet recorded anywhere in the world, a vertical peak motion of 1.74 times the force of gravity. This



Figure 4.—View of the six-story Imperial County Services Building located near the center of El Centro, California.

peak acceleration is of special interest in the engineering community because it is expected to have an impact on design criteria for critical structures such as nuclear powerplants. Overall, the data acquired from the El Centro ground-motion array during the October 15, 1979, earthquake have been of immense value in predicting the characteristics of strong ground shaking in future damaging earthquakes.

From an engineering point of view, by far the most significant data from this earthquake were those obtained from the heavily damaged six-story Imperial County Services Building (fig. 4), which is the tallest building in El Centro and in the surrounding region. Though the extent of damage was so severe that it is now likely that the building, designed in 1968 and constructed in 1971 at a cost of \$1.9 million, will have to be demolished; the fact that the building was instrumented with state-of-the-art earthquake recording instrumentation makes it a unique case study. The 13-channel strong-motion instrumentation network, designed by Survey personnel and installed and maintained by CDMG, accurately documented the partial collapse of the four reinforced-concrete columns at the east end between the second and ground floors

(figs. 5 and 6) as well as the damage that was caused by the subsequent settlement (8 inches during the main shock). The data provided a complete description of the response of the building to ground motion before, during, and after damage occurred. Moreover, these records are unprecedented, not only because this is the first occasion on which an extensively instrumented building has sustained earthquake-induced structural damage but because the time and mechanism of damage can be inferred from the recorded data. Already the subject of numerous research efforts, the data are expected to provide important information for improving building design and construction practice.

Since the October 15 earthquake, extensive geological and seismological investigations and

Figure 5.—Partial failure of the four columns along the east side of the Imperial County Services Building in El Centro, California.

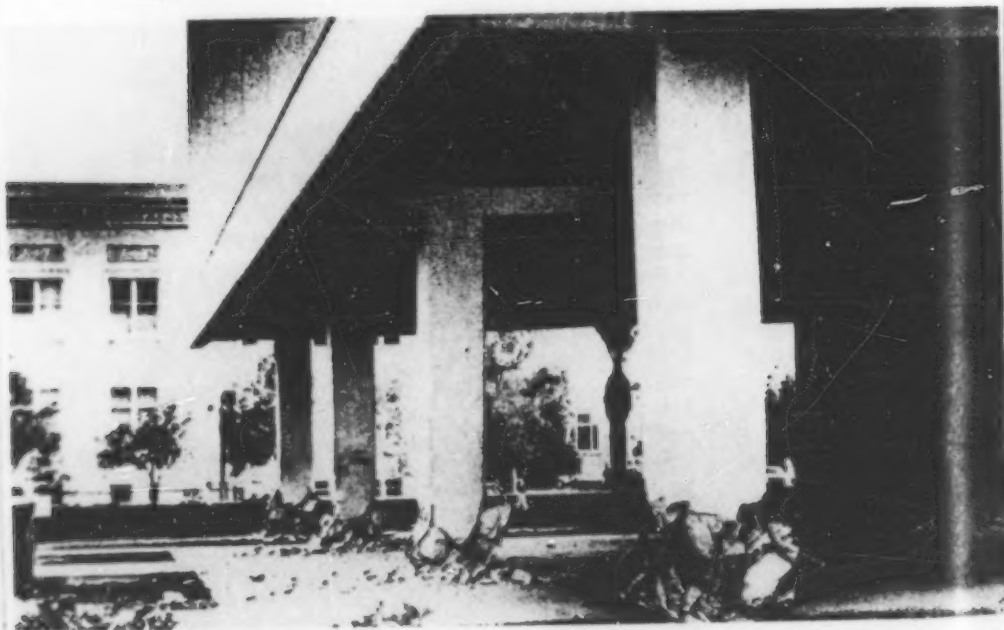




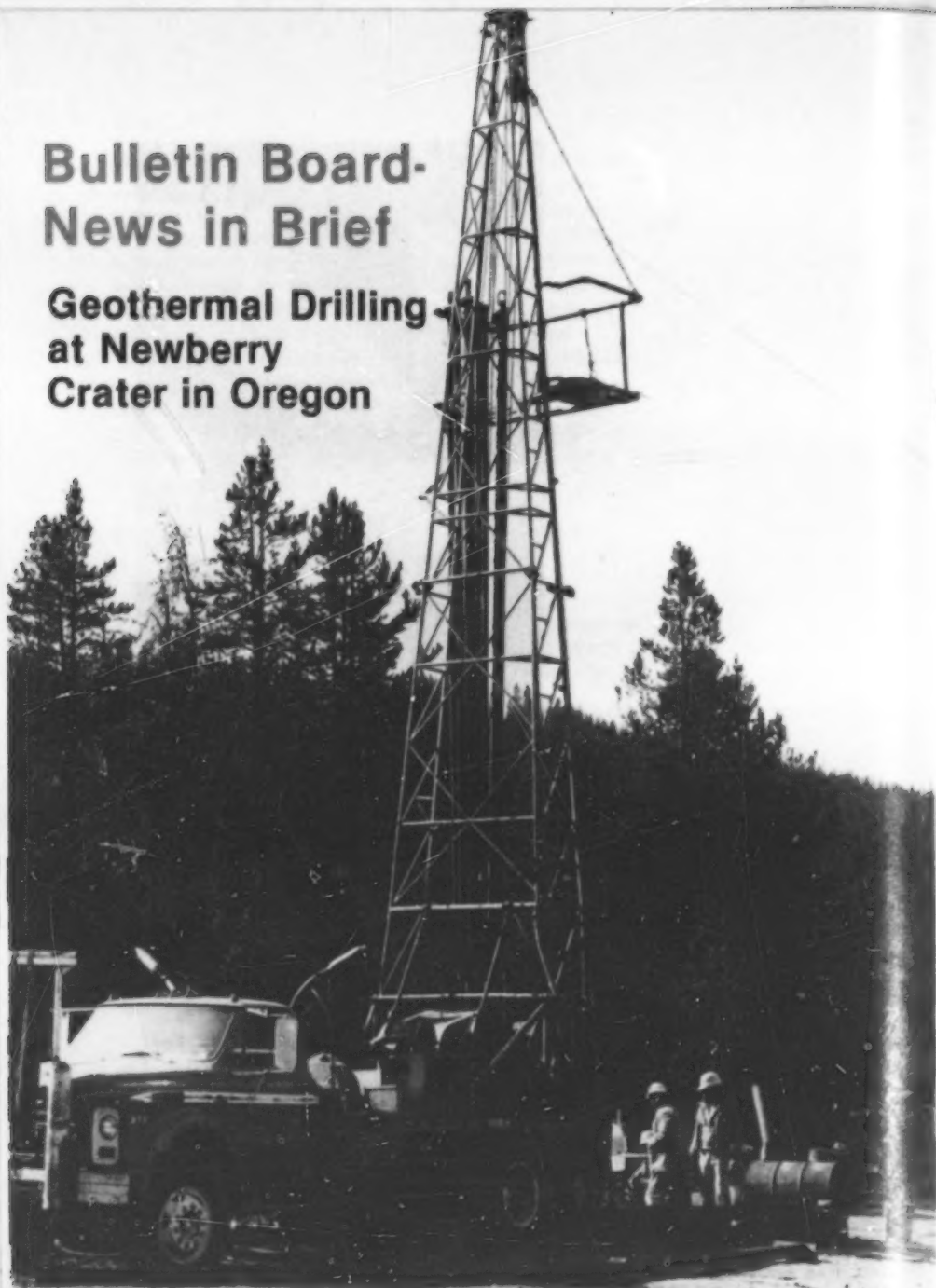
Figure 6.—View of one of the reinforced concrete columns between the ground and second floors.

monitoring efforts have been undertaken by scientists from the Survey and a number of other institutions. These investigations have yielded a number of new findings.

Since the main shock, the fault has continued to creep with displacements increasing by as much as 1 foot; surface faulting has occurred along the San Andreas and Superstition Hills faults located far to the north and west of the Imperial fault. The latter displacements, much smaller than those observed on the Imperial and Brawley faults nearer the shock epicenter, were probably "sympathetic" creep movements triggered by the earthquake or some of its aftershocks. Postearthquake studies also have shown that the 1979 surface rupture coincided with those of earlier historic and prehistoric offsets on the Imperial fault and that the surface rupture was confined to the fault segment northwest of the segment where exceptionally large horizontal shifts (up to 18 feet) occurred during the 1940 earthquake.

Bulletin Board- News in Brief

Geothermal Drilling at Newberry Crater in Oregon



Drilling rig at the geothermal test hole site.



View of Newberry Crater in Oregon. The test-hole site is shown by an arrow. The circular area in the right center is a lava flow 1,400 years old.

Drilling of a 3-inch-diameter geothermal test hole in the caldera of Newberry Crater near Bend in Oregon has been completed by the U.S. Geological Survey Geothermal Research Program. At that time, the well was 26,730 feet deep into massive lava flows, and the temperature at the bottom of the hole was 375 °F. Current work there is part of a regional evaluation of geothermal potential in the Cascades.

The U.S. Geological Survey Geologic Hazards Program

In 1879, Congress established the U.S. Geological Survey for "the classification of the public lands and the examination of the geological structure, mineral resources, and products of the national domain." Throughout the past 103 years, the Survey has successfully fulfilled these responsibilities, but it has also been responsive to changing national needs. This responsiveness is well exemplified by the development of the agency's natural hazard programs. Our original mission has been expanded to include formal investigations of earthquakes, volcanic eruptions, ground failures, and flood hazards.

The approach of the Geological Survey to geologic hazards consists of identifying and mapping the areas at risk from particular hazards, establishing recurrence intervals if possible, and conducting research on methods for predicting future hazards. This intensive research has led to significant advances in methods for reducing hazards risks and losses. For example, our operational monitoring networks in Hawaii and at Mount St. Helens have successfully predicted numerous volcanic eruptions, and our extensive hydrologic research has contributed greatly to the development of reliable flood-recurrence information. In southern California, we have established a prototype seismic network for earthquake prediction. The ap-

plication of scientific contributions like these is fundamental to public safety.

In addition to responsibility for acquiring scientifically valid hazard information, we have an equally strong obligation to warn the public of potential geologic hazards. Our warning system is comprised of three levels of increasing priority: (1) a notice of potential hazard, (2) a hazard watch, and (3) a hazard prediction. In applying this system, we have gone to great lengths to establish cooperative efforts in hazards mitigation with other Federal and State agencies and with local governments. To assist public officials in planning emergency operations, we include workshops as an integral part of our warning procedure. We have sought to increase public awareness of geologic hazards and to encourage longer range emergency planning through participation on national advisory councils with the Federal Emergency Management Agency and with cooperating officials in appropriate States. Additionally, we have tailored publications to meet hazard information needs of the general public and public officials.

All of our experience in hazard warning procedures has led us to recognize more acutely our own limitations in this vital area of government. We now realize, more than ever, that we must continue working vigorously as a partner with concerned groups at all levels to mitigate the effects of hazards across the nation.

Dallas L. Peck
Director
U.S. Geological Survey

The Role of the Volcanologist

The following was taken from Volcanological Aspects, volume 1 of Disaster Prevention and Mitigation, 1977, United Nations, 68 p. This publication was prepared with the cooperation of Gordon A. MacDonald of the Hawaii Institute of Geophysics.

The volcanologist should play a dual role. He should be both scientist and humanist. On the scientific side, he must gather, analyze, and interpret the data and attempt to predict the time and the type of the eruption and the nature and the extent of the damage from it. Prediction can be considered pure science, in that the degree of its fulfillment constitutes a test of the accuracy of the data and their interpretation and of the understanding of the volcanic mechanism. Obviously, it also has its very practical side because a successful prediction can mean a great saving of lives and property. The volcanologist must publicize his prediction, even at the risk of damage to his scientific reputation should he be wrong, and the basis for the prediction must be fully explained. Furthermore, the prediction and explanation must be made in plain language that can be understood by nonscientists. Specialized scientific terms and jargon must be avoided.

The volcanologist must develop the ability to work with nonscientists—the government officials and representatives of disaster-relief organizations—to understand their problems and needs to make them aware of what sort of information he can supply, its basis, and its limitations. He also must establish a rapport with residents of the areas concerned, not only with community leaders, but with the populace as a whole. They must come to know him, and he them. He must understand their feelings and reactions and their behavior under stress and try to lighten the stress by gaining their confidence. Panic is one of the most dangerous possibilities in any situation of

potential danger. Indeed, it can turn a situation that would otherwise not have been serious into a disaster. If the people have confidence in the volcanologist and he takes the pains to explain to them, in their own language, just what the situation is and what risks are involved, then the likelihood of panic can be much reduced. People show great ability to face dangerous situations with equanimity if they understand the situation. It is the unknown or not understood danger that terrifies. The mere presence of the volcanologist can inspire confidence and calm the situation.

There should, however, be a definite limit to the responsibilities of the volcanologist, and this should be understood by the general public. Thus, although it is his job to try to forecast a dangerous situation, it should not be his responsibility to order an evacuation. That should be done by a designated government official on the volcanologist's advice. The volcanologist should advise on the relative safety of evacuation routes, but the actual evacuation should be directed by officials of the police department or disaster-relief agencies following previously prepared plans, insofar as possible. He should advise of the feasibility of diverting flows, by barriers or by bombing, but the execution of the diversion should not be on his order. Economists should weigh the cost of the operation against the value of the property that may be saved; the probable legal implications should be considered by lawyers; and on the advice of all, the decision to divert the flow should be made by a high government official designated to assume the responsibility.

Not all scientists are psychologically fitted to deal with the human side of volcanology, and they should not attempt it. There are many places for them in collecting the scientific data and in interpreting it. Otherwise, with the best of intentions, they may soon alienate the people they are trying to help. Others, who are better suited, should make the contacts with the community.

Cascades Volcano Observatory

The David A. Johnston Cascades Volcano Observatory (CVO) dedicated on May 18, 1982, is the fourth observatory operated for the express purpose of monitoring volcanic activity in the United States. The prototype for CVO is the U.S. Geological Survey Hawaiian Volcano Observatory (HVO) located in the Hawaii Volcanoes National Park, on the island of Hawaii. HVO was originally established in 1912 and was administered by a variety of public and private agencies; the Survey has operated it since 1948. The second volcano observatory was established in 1926 at Mineral, California, to monitor the activity of Lassen Peak Volcano after the eruptions of 1914-17. A third observatory was established in 1927 on Kodiak Island,

Alaska, to monitor volcanic activity in Alaska. Both the second and third observatories were small-sized efforts coordinated by HVO; neither facility survived the depression.

In addition to work at Mount St. Helens, CVO scientists have been studying other Cascade volcanoes, including Mount Baker, Mount Hood, Crater Lake, Lassen Peak, Mount Shasta, and the Long Valley Caldera in California. CVO staffers also have monitored volcanoes in Indonesia, Hawaii, Central America, and Italy. Although CVO may not attract the attention that its Hawaiian sister enjoys as the single-most-seen Survey facility (an estimated 1,600,000 visitors in 1981), the new David A. Johnston Cascades Volcano Observatory will provide a highly visible contact between the Survey and the public.

Mount St. Helens showing the lava dome and deposits that resulted from the eruptive activity of March-April 1982. This activity was the 12th eruption since May 18, 1980. It produced an avalanche of pumice, ice, and rock debris, followed by a mudflow, which flowed north from the crater to Spirit Lake and the North Fork of the Toutle River. Two lobes were added to the composite dome in the crater. (Compare this photograph with other photographs of the developing dome in Earthquake Information Bulletin, vol. 12, no. 6, p. 221; vol. 13, no. 3, p. 98; vol. 13, no. 4, p. 143). (Photograph by Richard B. Waitt, Cascades Volcano Observatory, Washington.)



Working Group on the "Adequate Minimum" Volcanic Observatory

A working group consisting of R. I. Tilling (United States, Chairman), M. Esendola (Mexico), E. Majavassi (Costa Rica), L. Villari (Italy), and J. P. Viode (France) met on the island of Guadeloupe, on February 20, 1981, to discuss informally the requirements for a "minimum" volcano observatory, one which would have the essential monitoring equipment and staff to provide reliable information on the state of an active volcano. Given the premise that any monitoring of a volcano is better than none at all, the working group then proceeded to consider the concept of an "adequate minimum" observatory.

The group unanimously agreed that continuous recording of monitoring systems is absolutely essential for timely volcanic hazards warnings. The adequate minimum for such systems was determined to be the following:

1. A seismic network of three stations (short-period vertical seismometers, associated radio-link telemetry, and recording systems)—to locate the foci of seismic activity. Also a simple "tremor" or "seismic" alarm system must be an essential component, so that the observatory staff may be alerted even while at home during the night. A few additional hours advance notice of possible impending activity could result in significant reduction of casualties and damage.
2. A continuously recording tiltmeter (two components) with associated radio-link telemetry. This system should have at least one nonelectric tilt, measurement array ("dry tilt," water tube, and so forth) to serve as a check and a calibration.

In addition, the following activities were deemed by the group to be desirable to augment the adequate—minimum continuous monitoring mentioned above:

- Periodic reoccupation of a network of "dry tilt" stations.
- A modest trilateration (geodimeter) network and a few levelling lines—to permit at least the establishment of bench marks and initial baseline measurements.
- Observations of physical changes in the vicinity of the volcano—for example, appearance of new fumaroles and (or) changes in known fumarolic areas, ground cracking, minor landslides, other surface indicators of instability, unaccountable changes or damage of vegetation.
- Collection of information resources, documentation, manuals for instruments or monitoring techniques.
- Study of historical records to ascertain, at least, an historic eruptive pattern; geological mapping and other studies to improve understanding of prehistoric activity.

The working group also considered the matter of the adequate-minimum staff to effectively operate the observatory and concluded that it should have the following:

- Two geoscientists—one specializing in geophysics/seismology; another specializing in geology/geodesy.
- One electronics engineer or technician.
- Two general-purpose physical-science technicians.

Robert I. Tilling
U.S. Geological Survey
Reston, Virginia

"New" Antarctic Volcanoes

Two previously unknown volcanoes that show evidence of recent eruptions were discovered in March 1982 on the east side of the Antarctic Peninsula, according to the U.S. National Science Foundation. The discovery brings to five the number of known active volcanoes on the continent.

Volcanic debris still covers a large swath of the adjacent Larsen Ice Shelf, pointing to a very recent eruption. In addition, one of the volcanoes was steaming when the discovery was made, according to Oscar Gonzalez-Ferran of the University of Chile at Santiago. He made the discovery while doing a geophysical survey by helicopter of the Antarctic Peninsula. The two volcanoes constitute the southernmost extension of the eastern side of the "Ring of Fire," a ring of volcanoes that generally masks the edge of active plate tectonics around the Pacific Ocean. Both volcanoes are low, small cones of basalt; their heights were not reported.

Earthquake Quiz

(Answers elsewhere in issue. Modified after *Earthquakes, A Primer* by Bruce A. Bolt, W. H. Freeman and Company, San Francisco.)

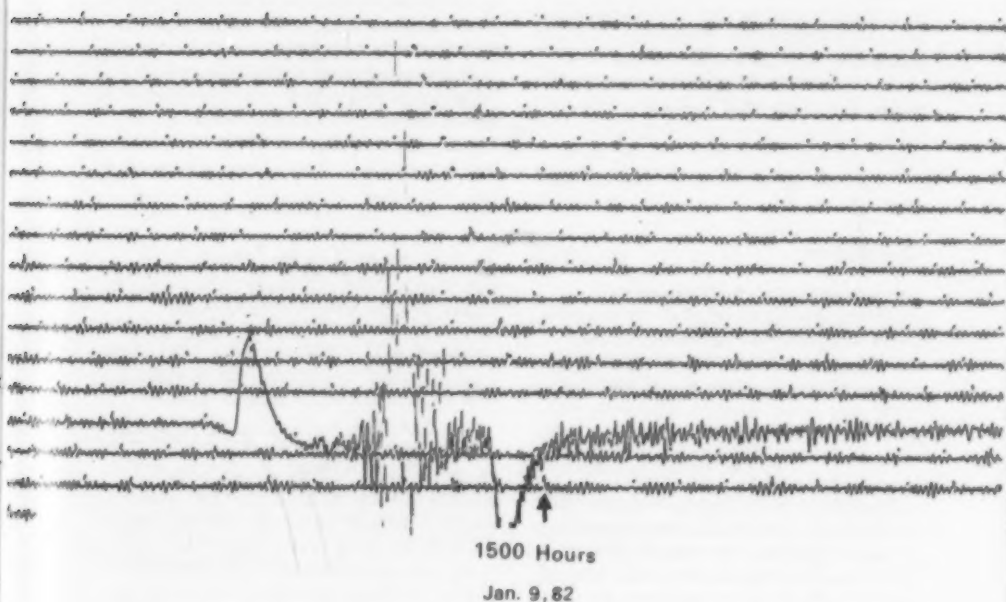
1. Why were the earliest seismographic stations established at astronomical observatories?
2. Why is the Earth's mantle likely to be solid?
3. How could an earthquake be detected on board ship?
4. At the present rate of slip on the San Andreas fault, say 1 inch per year, how long will it be before Los Angeles is a suburb of San Francisco?
5. You have just taken off in a plane. Will you know if a large earthquake then shakes the airport?

Miramichi, New Brunswick, Canada, Earthquakes of January 1982

The strongest earthquake since 1944 shook the Northeastern United States and southeastern Canada on January 9, 1982. The earthquake ($m_b = 5.9$) was centered in a sparsely populated area in central New Brunswick, Canada. Minor damage was reported in eastern Maine and parts of New Brunswick. The main shock was preceded by several small foreshocks and followed by an aftershock sequence that rapidly decayed until January 11 when a large aftershock ($m_b = 5.5$) took place. This aftershock was also widely felt in New England and New Brunswick. Intense aftershock activity followed, with over 1,000 events

located in the first week. Since then, the aftershocks have abated almost completely, although large aftershocks shook the area on April 1 and June 16. Historically, central New Brunswick has been an area prone to occasional small earthquakes. The January earthquakes took place in the middle of a large igneous plutonic body but somewhat remote from presently mapped faults. The aftershocks have provided the first recordings of earthquake strong ground motions in the Northeastern United States and Canada. Data from this sequence of events are of great interest to seismologists in the Eastern United States and Canada.

John Ebel,
Western Observatory,
Boston College, Massachusetts



Record of the January 9, 1982, Miramichi, New Brunswick, Canada, earthquake taken at the Weston Observatory.

EARTHQUAKES

March-April 1982

By Waverly J. Person,
National Earthquake Information
Service, U.S. Geological Survey,
Denver, Colorado

The earthquake activity during this reporting period was somewhat quiet as far as significant earthquakes were concerned. There were no major (magnitude (M) = 7.0-7.9) earthquakes during this reporting period, but five people were reported killed in Peru from earthquakes on March 24 and 28.

A number of earthquakes occurred in the United States, but no damage was reported.

Idaho

A small earthquake occurred in the southeastern part of this State on March 1 at 3:43 p.m. MST. The magnitude 3.6 earthquake was located about 59 miles southeast of Idaho Falls near the Wyoming border. The quake was felt in the areas of Etna, Freedom, and Thayne, Wyoming; maximum intensity registered IV on the Modified Mercalli Intensity Scale (MM).

Washington

A light earthquake shook parts of southwestern Washington on March 1 at 9:40 a.m. PST. The magnitude 4.1 earthquake was located about 12 miles northwest of Mount St. Helens, and MM V effects were experienced at Glenoma and Silver Creek. It was also felt in other areas of Lewis County, in most parts of Cowlitz County, and also in Clark County.

On April 13 at 11:23 p.m. PST, the north-central part of the State experienced a minor earthquake. The magnitude 3.1 quake was located about 6 miles west of Seattle, and MM IV effects were experienced at Olalia and Port Orchard. It was also felt in the areas of Bremerton, Dockton, Fort Gamble, Ollicene, Seattle, and Wauna.

South Carolina

The north-central part of this State experienced two very minor earthquakes on March 2 at 11:48 a.m. EST and on April 13 at 4:25 a.m. EST. The March 2 quake had a magnitude of 2.8, and the April 13 quake had a magnitude of 2.7; they were located about 31 miles northwest of Columbia in the Jenkinsville-Monticello area. Both tremors were felt in the Jenkinsville-Little Mountain-Monticello areas.

California

This State was shaken by a number of earthquakes during this reporting period, but most had magnitudes of less than 4.0. On March 7 at 12:50 p.m. PST, the central part of the State experienced a light earthquake. The magnitude 4.3 quake was located about 19 miles southwest of China Lake. MM V effects were noted in the Inyokern-Ridgecrest area. It was felt in other areas of Kern County and in part of San Bernardino County.

The southern part of the State experienced a sharp earthquake on March 22 at 12:53 a.m. PST. The magnitude 4.5 earthquake was located about 59 miles northeast of San Diego. The quake was felt over a wide area from Palm Springs south to the Mexican border (MM IV).

On March 24 at 6:28 p.m. PST, the northern part of California was shaken by a light earthquake. The magnitude 4.0 earthquake was centered about 34 miles southeast of Ukiah. MM IV effects were experienced in the Cobb, Finley, and Loch Lomond areas. It was also felt at Geyserville, Healdsburg, and Middletown.

The California-Nevada border region experienced a moderate earthquake on April 15 at 1:52 p.m. PST. The magnitude 5.2 earthquake was located about 43 miles north of Bishop, California. MM IV effects were noted at Lee Vining, and MM III effects were experienced in the areas of Bishop, Bridgeport, Benton, El Portal, Independence, and Merced, California. The quake was also felt in the areas of Babbitt, Dyer, Goldfield, Hawthorne, Schurz, and Yerington, Nevada.

Colorado

This State experienced a very minor earthquake on March 11 at 4:55 p.m. MST. The magnitude 2.8 tremor was located about 12 miles north of downtown Denver in the Thornton area. It was felt in the Commerce City, Northglenn, and Thornton areas. MM III effects were experienced in the Thornton area.

New Mexico

The northeastern part of New Mexico was shaken by a minor earthquake on March 16 at 4:03 a.m. MST. The magnitude 3.1 earthquake was located about 31 miles east of Tucumcari and was felt in the Logan area.

Hawaii

Hawaii experienced a number of earthquakes during this reporting period, but most had magnitudes less than 4.0. Two earthquakes were located on the southeastern part of the big island on March 20 at 1:10 p.m. HST and April 11 at 4:04 p.m. HST; the quakes had magnitudes of 4.3 and 4.4, respectively. Both quakes were felt over most of the island. There were no reports of damage.

Japan

The southern part of Hokkaido was struck by a strong earthquake on March 21. The magnitude 6.8 earthquake was centered about 90 miles southeast of Sapporo near the south coast. One hundred ten people were reported injured, and damage was reported in southern Hokkaido. A local tsunami occurred at Hachinohe, but no damage was experienced from the tsunami. A number of aftershocks followed; the largest was a magnitude 6.0 on the same day as the main shock, but no additional casualties or damage were reported.

Peru

The central part of this country experienced a damaging earthquake on

March 23. This magnitude 4.9 earthquake was centered in the Lima area where two people were killed and some damage occurred.

On March 28, the area about 87 miles to the southeast of Lima was struck by a strong earthquake. The magnitude 6.0 earthquake killed three people and caused considerable damage in the Lunahuana area. It was also felt in the Huancayo and Lima areas.

Canada

The southeastern part of this country continues to experience some light earthquakes following the main shock on January 9 (see *Earthquake Information Bulletin*, vol. 14, no. 4, p.). The latest shocks in this magnitude range occurred on March 31 at 4:02 p.m. EST and on April 11 at 1:01 p.m. EDT; these earthquakes had magnitudes of 4.5 and 4.0, respectively, and were located in New Brunswick about 62 miles north of Fredericton and 62 miles east of Presque Isle, Maine. The first shock was felt throughout most of New Brunswick and in parts of Maine. The latter shock was felt in the areas of Caribou, Limestone, and Van Buren, Maine. There were no reports of damage.

Paraguay

The southeastern part of this country experienced a rare earthquake on April 8. The magnitude 5.1 earthquake was located a few miles north of Asuncion and some minor damage was reported in the Asuncion area.

Republic of South Africa

A moderate earthquake occurred in the gold mining area of this country on April 13. The magnitude 5.0 earthquake was centered about 149 miles southwest of Johannesburg, just to the north of Welcom. Two people were reported killed, and 20 were injured by rockslides in a gold mine.

New Jersey

The west-central part of this State was surprised by a minor earthquake on April 12 at 5:15 p.m. EST. The magnitude 2.8 tremor was located in the Mount Holly area near the Pennsylvania border. The tremor was felt in parts of Burlington, Camden, and Mercer Counties, New Jersey, and in the southeastern parts of Buck and Montgomery Counties, Pennsylvania. MM V effects were experienced at Mount Holly and Maple Shade, New Jersey and Croyden, Pennsylvania.

Alaska

The State of Alaska experienced a number of earthquakes during this reporting period, but most were in the smaller magnitude range. The largest was a magnitude 5.3 in the Alaskan Peninsula area on April 15 at 6:21 a.m. AST. This shock was located about 62 miles south of Cold Bay. It was felt at Cold Bay and Sand Point (MM IV).

U.S. Activity*

Alaska	6
California	20
Colorado	1
Hawaii	26
Idaho	1
Maine	2
Nevada	1
New Jersey	1
New Mexico	1
Pennsylvania	1
South Carolina	2
Washington	2
Total	64

*Felt earthquakes as reported from many sources.

Volcano Quiz

(Answers elsewhere in issue)

1. What was the date of the cataclysmic eruption of Mount St. Helens Volcano?
2. Where is Mount Pelée? When did it erupt?
3. What is the Giant's Causeway? Where is it?
4. What were the names of the two cities buried by the eruption of Mount Vesuvius in A.D. 79?
5. Name some of the 15 volcanoes in the Cascade Range of the Pacific northwest.

Preliminary Locations

March-April 1982

Date	Origin time	Region	Coordinates		Depth (km)	Magnitude		
			Latitude	Longitude				
Mar 1-----10	43	06.0	Eastern Idaho-----	43.0 N	111.1 W	5	13.6 M _L	
	17	40	04.5	Washington-----	46.4 N	122.3 W	12	4.1 M _L
Mar 2-----16	48	08.4	South Carolina-----	34.3 N	81.4 W	5	2.8 m _{bLg}	
Mar 7-----20	50	12.8	Central California-----	35.8 N	117.8 W	2	4.3 M _L	
Mar 11-----23	55	28.7	Colorado-----	39.9 N	104.9 W	5	2.8 M _L	
Mar 16-----11	03	02.4	New Mexico-----	35.3 N	103.3 W	5	3.1 m _{bLg}	
Mar 20-----23	10	22.3	Hawaii-----	19.3 N	155.3 W	36	4.3 DUR	
Mar 21-----02	32	06.3	Hokkaido, Japan, region.	42.5 N	142.5 W	33	6.8 M _S	
Mar 22-----08	53	28.6	Southern California.	33.1 N	116.2 W	5	4.5 M _L	
Mar 23-----05	10	07	Peru-----	12.3 S	77.6 W	57	4.9 m _b	
Mar 25-----02	27	32.5	Northern California.	38.8 N	128.8 W	2	4.0 M _L	
Mar 26-----23	24	50.7	Near coast of Peru.	12.8 S	76.1 W	95	6.0 m _b	
Mar 31-----21	02	20.0	New Brunswick-----	47.0 N	66.6 W	5	4.5 m _{bLg}	
Apr 8-----05	58	52.0	Paraguay-----	24.8 S	58.1 W	33	5.1 M _L	
Apr 11-----18	00	51.4	New Brunswick-----	47.0 N	66.6 W	5	4.0 m _{bLg}	
Apr 12-----02	04	03.0	Hawaii-----	19.3 N	155.1 W	9	4.0 M _L	
	22	14	30.8	New Jersey-----	40.0 N	74.8 W	5	2.8 m _{bLg}
Apr 13-----09	25	19.0	South Carolina-----	34.3 N	81.4 W	5	2.7 m _{bLg}	
	11	26	51.7	Republic of South Africa.	27.4 S	27.4 E	10	5.0 m _b
Apr 14-----07	22	43.4	Washington-----	47.6 N	122.5 W	26	3.1 M _L	
Apr 15-----16	21	14.9	Alaska Peninsula-----	54.2 N	161.7 W	61	5.3 m _b	
	21	52	08.8	California-Nevada border region.	38.0 N	118.5 W	20	4.7 m _b

¹Richter magnitude.

²Magnitude from Love waves.

³Duration.

⁴Magnitude from surface waves.

⁵Magnitude from body waves.



Magnitude ≥ 6.0 Earthquakes

Preliminary Locations

January-June 1982

[BRK = Berkeley; PAS = Pasadena; m_b = magnitude from body waves; M_S = magnitude from surface waves]

Date	Origin time	Region	Coordinates		Depth (km)	Magnitude (≥ 6.0)
			Latitude	Longitude		
Jan 1----18	51 01.5	Bonin Islands region.	26.8 N	142.6 W	22	6.4 m_b 6.7 M_S 6.5 M_S (BRK) 6.5 M_S (PAS)
Jan 3----14	09 50.4	Central Mid-Atlantic Ridge.	1.0 S	21.9 W	10	5.8 m_b 6.5 M_S 6.3 M_S (PAS)
Jan 4----06	05 01.3	Mariana Islands.	18.0 N	145.6 E	590	6.1 m_b
	22 20 53.6	South of Fiji Islands.	23.2 S	177.3 W	195	6.0 m_b
Jan 11----06	10 06.4	Luzon, Philippine Islands.	13.8 N	124.4 E	46	6.0 m_b 7.1 M_S 7.2 M_S (BRK) 7.4 M_S (PAS)
Jan 12----05	48 17.6	Honduras-----	13.2 N	87.6 W	6	5.8 m_b 6.0 M_S 6.2 M_S (PAS)
Jan 13----00	06 43.2	Deniŕecasteaux Islands region.	9.6 S	152.2 E	33	6.0 m_b 6.0 M_S 6.0 M_S (BRK) 5.8 M_S (PAS)

Magnitude ≥ 6.0 Earthquakes—Continued

Date	Origin time	Region	Coordinates		Depth (km)	Magnitude (≥ 6.0)
			Latitude	Longitude		
Jan 14___09	53	45.4	----- do -----	9.5 S 152.0 E	33	5.7 m_b 5.9 M_S 6.1 M_S (BRK)
Jan 15___13	46	21.8	----- do -----	9.5 S 152.2 E	33	5.9 m_b 6.0 M_S 5.8 M_S (PAS)
Jan 18___04	23	37.7	Vanuatau Islands.	17.3 S 167.8 E	44	5.4 m_b 5.6 M_S 6.0 m_b (BRK)
	19	27	24.4 Aegean Sea	40.0 N 29.3 E	10	5.8 m_b 6.9 M_S 6.8 M_S (BRK) 7.0 M_S (PAS)
Jan 20___04	25	11.6	Nicobar Islands region.	7.0 N 94.0 E	19	5.6 m_b 6.3 M_S 6.0 M_S (PAS)
	07	09	17.4 ----- do -----	7.1 N 94.0 E	39	5.7 m_b 6.2 M_S
Jan 23___17	37	30.2	Tibet	31.7 N 82.3 E	33	6.0 m_b 6.5 M_S 6.2 M_S (PAS)
	17	48	02.1 ----- do -----	31.6 N 82.2 E	33	5.4 m_b 6.0 M_S
Jan 24___06	08	56.6	Luzon, Philippine Islands.	14.1 N 124.4 E	37	5.6 m_b 6.4 M_S 6.6 M_S (PAS)
Jan 25___05	29	33.5	Fox Islands, Aleutian Islands.	53.2 N 165.7 W	60	6.1 m_b 6.5 m_b (BRK) 6.4 m_b (PAS)
Jan 30___02	35	10.6	Leeward Islands.	16.7 N 61.4 W	63	6.0 m_b 5.6 M_S (PAS)
Feb 20___13	26	50.3	Santa Cruz Islands.	10.9 S 166.0 E	36	6.0 m_b 6.8 M_S 6.8 M_S (BRK) 6.6 M_S (PAS)
	19	18	20.2 South of Honshu, Japan.	33.6 N 141.0 E	18	6.2 m_b 6.5 M_S 6.5 M_S (BRK) 6.6 M_S (PAS)
Mar 4___09	11	49.5	Loyaity Islands region.	22.4 S 173.6 E	45	5.6 m_b 6.0 M_S 5.9 M_S (BRK)
Mar 10___21	58	43.5	South Sandwich Islands region.	56.0 S 27.3 W	102	6.0 m_b
Mar 11___10	32	27.1	Sumbawa Islands	9.3 S 118.5 E	33	6.1 m_b 6.4 M_S 6.5 M_S (BRK) 6.2 M_S (PAS)

Magnitude ≥ 6.0 Earthquakes—Continued

Date	Origin time	Region	Coordinates		Depth (km)	Magnitude (≥ 6.0)
			Latitude	Longitude		
Mar 21____02	32 07.7	Hokkaido, Japan, region.	42.2 N	142.4 E	44	6.4 m _b 6.7 M _S 6.4 M _S (PAS) 6.4 M _S (BRK)
Mar 25____05	05 39.6	South Atlantic Ocean.	52.7 S	46.8 W	10	6.0 m _b 6.0 M _S 6.1 M _S (PAS)
Mar 27____00	19 25.6	Near east coast of Honshu, Japan.	34.7 N	140.8 E	20	5.6 m _b 5.7 M _S 6.1 M _S (PAS) 6.2 m _b (PAS)
Mar 26____03	13 45	Solomon Islands	11.1 S	162.9 E	73	5.5 m _b
	52 34.5	Kermadec Islands.	31.5 S	178.7 W	79	6.0 m _b 6.1 M _S (PAS)
	23 24	Near coast of Peru.	12.7 S	76.1 W	95	6.1 m _b
Mar 29____12	20 26.7	Fiji Islands region.	15.5 S	179.6 W	33	5.8 m _b 6.3 m _s
	21 33	Minahassa Peninsula.	0.1 N	123.3 E	187	6.0 m _b
Apr 6_____19	56 53.7	Coast of Chiapas, Mexico.	14.3 N	92.1 W	65	6.0 m _b 6.5 M _S 6.8 M _S (BRK) 6.3 m _b (PAS)
Apr 12____00	34 44.3	Kermadec Islands.	30.2 S	177.9 W	35	5.7 m _b 6.1 M _S 6.2 M _S (BRK) 5.7 M _S (PAS)
Apr 16____14	04 51.2	Tonga Islands.	15.8 S	173.0 W	33	6.0 m _b 6.0 M _S 6.4 M _S (BRK) 6.2 M _S (PAS)
Apr 17____09	20 57.8	Philippine Islands region.	19.9 N	120.5 E	10	6.2 m _b 6.0 M _S 5.8 M _S (BRK)
May 2____11	19 41.6	Kermadec Islands.	29.2 S	177.3 W	54	5.8 m _b 6.6 M _S 6.6 M _S (BRK) 6.3 M _S (PAS)
May 7____05	38 34.5	Southwestern Atlantic Ocean.	60.7 S	20.8 W	10	6.1 m _b 6.7 M _S 6.5 M _S (PAS)
May 23____21	32 34.9	Gilbert Islands.	3.4 N	177.4 E	32	6.0 m _b 5.7 M _S 6.1 M _S (BRK) 5.5 M _S (PAS)
May 24____07	25 32.4	Kuril Islands.	48.9 N	155.0 E	29	6.0 m _b 5.3 M _S

Magnitude ≥ 6.0 Earthquakes—Continued

Date	Origin time		Region	Coordinates		Depth (km)	Magnitude (≥ 6.0)
				Latitude	Longitude		
May 31__10	21	14.8	Komandorsky Islands region.	55.1 N	165.4 E	33	5.9 m_b 6.5 M_S 6.2 M_S (BRK) 6.1 M_S (PAS)
	15	18	West Carolina Islands.	7.8 N	135.7 E	33	5.8 m_b 6.4 M_S 6.0 M_S (BRK) 6.1 M_S (PAS)
Jun 1____04	14	15.3	Off coast of southern Chile.	41.6 S	75.0 W	32	6.1 m_b 6.3 M_S 6.0 M_S (BRK) 5.8 M_S (PAS)
Jun 2____12	37	34.6	Tonga Islands region.	18.0 S	172.6 W	33	6.4 m_b 6.4 M_S 6.4 M_S (BRK) 6.2 M_S (PAS)
Jun 6____23	40	56.6	-----do-----	18.0 S	172.4 W	33	5.1 m_b 6.1 M_S
Jun 7____06	52	38.5	Near coast of Guerrero, Mexico.	16.6 N	98.2 W	51	5.9 m_b 6.8 M_S 7.2 M_S (BRK) 6.7 M_S (PAS)
	10	59	-----do-----	16.6 N	98.3 W	39	6.0 m_b 7.0 M_S 6.9 M_S (BRK) 6.3 M_S (PAS)
Jun 09____03	08	34.3	New Britain region.	5.7 S	151.0 E	76	5.8 m_b 6.3 M_S 6.5 M_S (BRK) 6.5 M_S (PAS)
Jun 11____00	38	09.7	Tonga Islands	17.5 S	174.5 W	124	6.3 m_b 6.9 m_b (PAS)
Jun 19____06	21	57.4	El Salvador	13.3 N	89.4 W	83	6.1 m_b 7.4 M_S (BRK) 7.0 M_S (PAS) 7.0 M_S (PAS)
Jun 22____04	18	40.5	Banda Sea	7.4 S	126.1 E	450	6.2 m_b
Jun 27____16	17	13.4	Macquarie Islands region.	55.4 S	160.4 E	10	5.9 m_b
Jun 30____01	57	34.3	Kuril Islands region.	44.7 N	151.2 E	33	6.6 m_b 6.8 M_S 6.9 M_S (BRK) 6.8 M_S (PAS)

Announcements

Emergency 82

An International Congress and exhibition for Emergency, Disaster Preparedness and Relief, will be held from October 20 to 22, 1982, Geneva, Switzerland.

The program has been established by experts from the United National Disaster Relief Coordinator, the International Civil Defence Organization, and the League of Red Cross and Red Crescent Societies. It is divided into 3 days, each dedicated to a main theme:

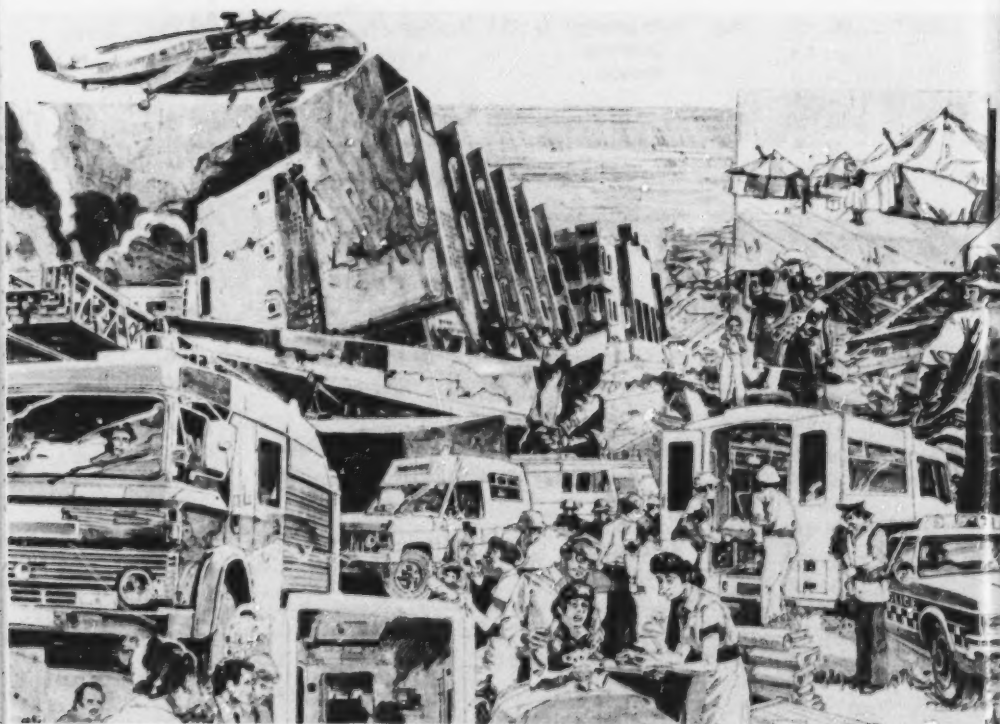
- Preparedness—Formulation of Emergency Plans;
- Relief—Implementation of Emergency Plan; and

- Practical case study—El Asnam, Algeria 1980.

Each theme covers several subjects to be introduced by specialists who will initiate discussion on the best possible measures to achieve protection and survival of populations threatened by all kinds of disasters. The official languages of the congress are English, French, Arabic, and Spanish. A simultaneous interpretation service will be in operation during the presentations and discussions. A fourth day, October 23, devoted to fire-fighting is being organized by the European Committee of the Manufacturers of Fire Protection Equipment.

For more information write to:

EMERGENCY 82 Congress Secretariat
P.O. Box 112, CH-1218 Grand Saconnex
Geneva, Switzerland



Earthquake Engineering Research Institute

Two regional Seminars on Earthquake Fundamentals, including geology, seismology, strong motion records, earthquake damage, seismic analysis, and seismic design will be held in

Salt Lake City, Utah
A. Ray Olpin University Union Building
University of Utah
October 4-5, 1982

and in

Raleigh, North Carolina
McKimmon Center
North Carolina State University
October 18-19, 1982

For information contact:

Lawrence D. Reaveley
Reaveley Engineers and Associates, Inc.
2126 South 10th East
Salt Lake City, Utah 84106
(801) 486-3883;

Naser Mostaghel
Professor of Civil Engineering
3012 Merrill Engineering Building
Salt Lake City, Utah 84112
(801) 581-6931; or

Ajaya K. Gupta
Assoc. Professor of Civil Engineering
North Carolina State University
Raleigh, North Carolina 27650

South Asia Natural Disasters Workshop

The theme of this workshop, to be held at Vishwa Yurak Kendra, New Delhi, India, from October 9 to 16, 1982, is "Information for Survival," and it is hoped that the media in South Asia and in particular the Indian Subcontinent will benefit from it. The workshop coordinators are Hameeduddin Mahmood and Narendra Kumar Jain.

The following media have been targeted:

- *Print Media*—Editors and reporters of news agencies, dailies, and periodicals; media managers as well as press photographers.
- *Broadcast Media*—Radio and television correspondents, newsreel and documentary producers, and script writers.
- *Audio-Visual and Film Media*—Directors, producers, and cameramen.
- *Other Visual Media*—Organizers of exhibitions.

The following are objectives of the workshop:

- Making the media an effective instrument to make people aware and responsive to imminent disasters and developing a system of warning and action against disasters.
- The nature and hazards of disaster reporting and the steps that need to be taken by the Government and media administrators, as a matter of public policy, to develop disaster reporting as a specialized media discipline.
- The manner, techniques, and problems of media coverage of natural disasters in various countries.

For further information, write to:

Mr. B. M. Lal
Director (Admn.)
Joint Assistance Centre
H-65, South Extension-I
New Delhi-110049
India

International Earthquake Conference

Organized by the City of Los Angeles, University of Southern California, Southern California Earthquake Preparedness Project, Federal Emergency Management Agency, and the U.S. Agency for International Development Office of Foreign Disaster Assistance. Los Angeles, California: February 7-11, 1983.

The program, designed for policymakers and administrators, will focus on what is necessary to local governments to develop, to evaluate, and to implement earthquake mitigation and response policies. Researchers will have an opportunity to present their findings and receive suggestions from practitioners about future research needs. Sessions will address all facets of earthquake preparedness and response for police, fire, health and building safety departments, schools, volunteer organizations, utilities, the media, and business and industry.

Request more information, contact:

Councilman Hal Bernson
City Hall
Room 236
200 North Spring Street
Los Angeles, California 90012-4190

or call:

Edna Bruce
(213) 485-5613.

Answers to Earthquake Quiz

1. Because astronomical observatories keep accurate time.
2. Because it allows seismic secondary (S) waves to pass through, and these are not transmitted through fluid.
3. By means of the primary (P) wave.
4. About 20 million years.
5. Probably not, if your eyes are shut, because seismic air waves are too small. (You would of course have an excellent bird's-eye view of the earthquake effects.)

Answers to Volcano Quiz

1. May 18, 1980.
2. A volcano on the island of Martinique in the Lesser Antilles of the Caribbean. May 7, 1902.
3. An outcrop of basalt columns off the coast of County Antrim, Northern Ireland. The columns are six sided and about 20 inches in diameter and were formed by extremely slow cooling of lava about 50 million years ago. Similar hexagonal jointing in basalt due to cooling is found on the island of Staffa, western Scotland, at the Devil's Postpile, Sierra Nevada, and at the Devil's Tower National Monument, Wyoming.
4. Pompeii and Herculaneum.
5. Mounts Adams, Baker, Jefferson, Garibaldi, Hood, McLoughlin, Rainier, Shasta, St. Helens, Thielsen; Crater Lake (Mount Mazama); Glacier and Lassen Peaks; Newberry Crater and The Three Sisters.

About the Author

Dr. Robert Tilling has recently returned to active research on volcanic phenomena after serving administrative tours as the Scientist-in-Charge of the Hawaiian Volcano Observatory and as the Chief of the Office of Geochemistry and Geophysics, which has responsibility for the Volcano Hazards Program of the U.S. Geological Survey. He was in overall charge of the scientific studies at Mount St. Helens during 1980 and 1981.



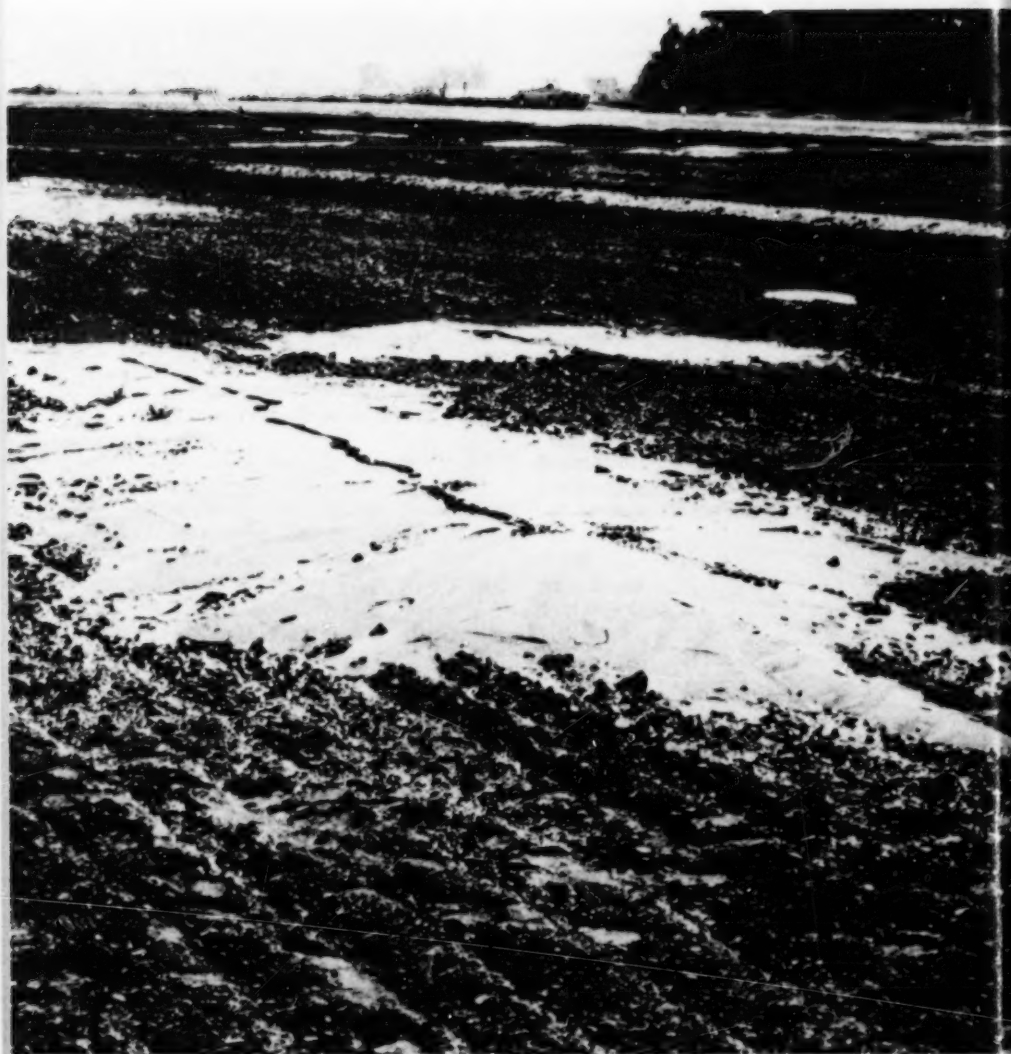
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Sand boils generated in a field during the 1979 Imperial Valley earthquake in California. Sand boils are the ejection of sand and water as a result of artesian pore-water pressures developing during the liquefaction process.

14/6



UNITED STATES
DEPARTMENT
OF THE
INTERIOR
GEOLOGICAL
SURVEY

Earthquake Information Bulletin

November-December 1982, Volume 14, Number 6



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**UNITED STATES DEPARTMENT OF THE
INTERIOR**

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

EARTHQUAKE INFORMATION BULLETIN is published bimonthly by the U.S. Geological Survey to provide current information on earthquakes and seismologic, volcanologic, and related activities of interest to both general and specialized readers. The Secretary of the Interior has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through June 30, 1984.

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Earthquake Information Bulletin



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Cover: Docks, rail yards, and fuel tanks destroyed during the Seward, Alaska, earthquake of March 27, 1964. (Army Mohawk Aircraft photograph.)

Evidence for Ancient Rifting in the New Madrid Earthquake Zone, Missouri

Earth scientists and the general public are becoming increasingly aware of the damage and loss of life that would be caused by a repetition of the major earthquakes that occurred near New Madrid, Missouri, in 1811 and 1812. The intensities of these events ranged between X and XII on the Modified Mercalli Intensity Scale (see list, this issue).

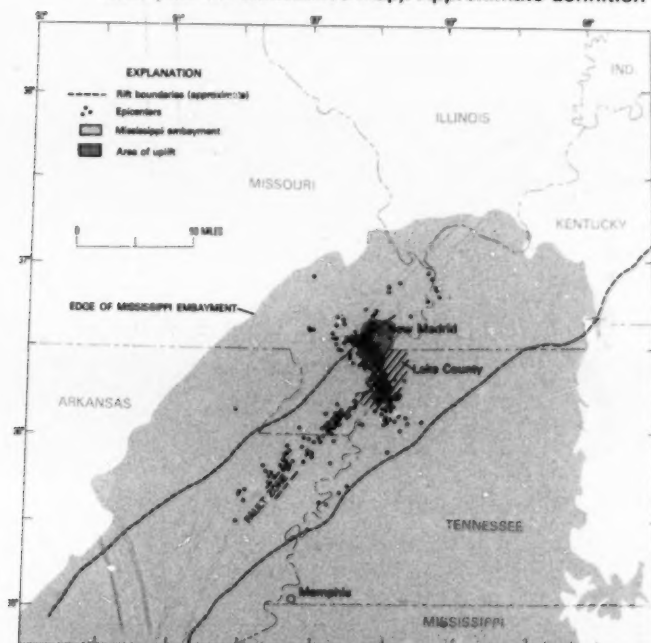
Because of the greater thickness of the Earth's crust in the Central United States, the geographic area that would be affected by such earthquakes is much larger than if the same earthquakes occurred in the Western United States. This unique characteristic is of critical importance in evaluating the seismic hazards of the Central United States. It is vividly illustrated by comparing the present population within the areas of damage of the New Madrid earthquake of February 7, 1812, and the San Francisco earthquake of 1906. More than 12 million people live within the damage area for the New Madrid earthquake, yet only about 4 million people presently live in the area that was affected by the San Francisco earthquake.

A multidisciplinary effort that was started on a small scale in 1974 to investigate earthquakes in the New Madrid region has resulted in information that has greatly advanced our understanding of the New Madrid earthquakes. In particular, it has provided some rational concepts that will be useful for evaluating seismic hazard. Taking part in this effort are Federal, State, and academic scientific communities that are funded largely through the Earthquake Hazards Reduction Program of the U.S. Geological Survey. In addition, the Nuclear Regulatory Commission has provided funding to States and academic organizations under a seven-state (Alabama, Arkansas, Illinois, Indiana, Kentucky, Missouri, and Tennessee) cooperative program. Its principal objective is to provide earth science information for assessing the seismic hazards to nuclear powerplants in

the region. The multidisciplinary effort has included collecting seismic, aeromagnetic, gravity, geomorphic, tectonic, seismic refraction, and seismic reflection data.

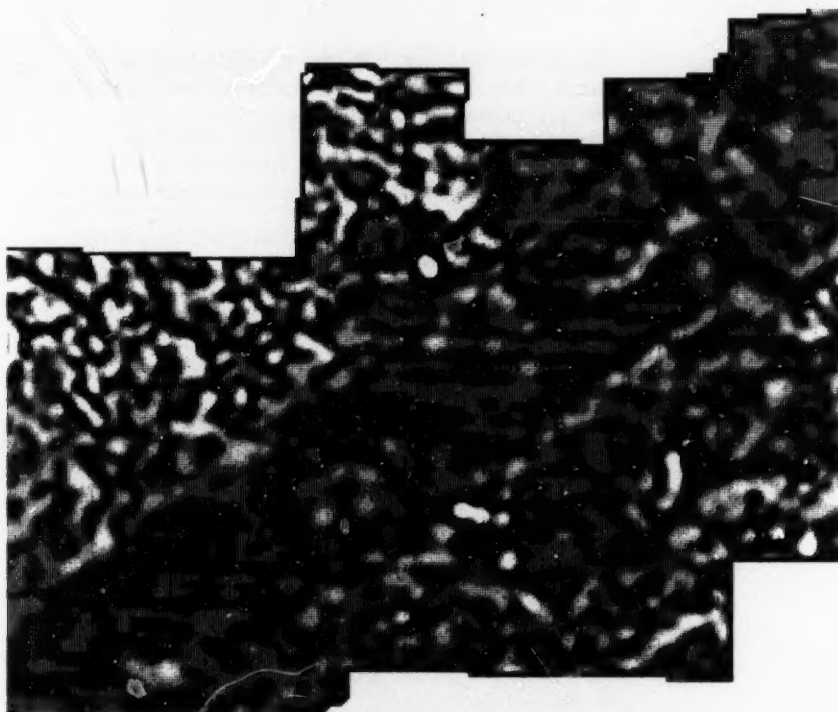
Analysis of the data indicates that most earthquakes in the region are associated with an ancient rift in the Earth's crust, which may be similar to rifts in east Africa and the Rhine River region in Germany. Major rifting in the New Madrid region appears to have begun 500 million to 700 million years ago. Igneous activity (injection of molten magma into the Earth's crust) and faulting in or near the rift have occurred periodically at least three times since the initial major rifting.

The seismic data have provided the first subsurface indication of the approximate location of the seismically active fault zones. Alignments of epicenters (surface locations of earthquakes) have a prominent northeast trend; less prominent trends are north-northwest and west (see the boundaries map). Approximate definition



Map showing the approximate boundaries of the rift as a dashed line, the location of a subsurface fault zone, the area of uplift (color), and epicenters within the Mississippi embayment.

of the buried rifts is most evident in aeromagnetic data (see photograph). They indicate a trough in the magnetic basement that trends northeast and is about 42 miles wide and more than 120 miles long; the bottom of the trough is at a depth of about 3 miles. The aeromagnetic data, along with evidence from exploratory drill holes and abundant outcrops of alkalic rocks that commonly are found in rifts all over the world, are the principal basis for inferring that the trough in the New Madrid region is a rift within the North American crustal plate.



Maps of anomalies in the Earth's magnetic field as it is recorded from high altitude (aeromagnetic maps) outline a prominent northeast-trending trough at the northern end of the Mississippi embayment. The axis of this trough closely coincides with the pattern of seismicity that is now being measured in the area.

Interpretation of seismic reflection profile data shows a fault zone with an aggregate vertical displacement of about 0.6 mile, which appears to be associated with the longest trend of seismic activity. This faulting occurred prior to the deposition of most Paleozoic (about 240-million to 570-million-year-old) rocks. The location of the fault zone and longest trend of seismicity are along the axis of the inferred rift. All post-Paleozoic faults in the reflection profiles have less than 300 feet of vertical off-set. The reflection profiles also indicate that some faults and slight bending of sedimentary rocks are associated with small masses of volcanic rocks which did not reach the surface of the Earth.

Subtle uplift (see the shaded outline in the boundary map) of the alluvial flood plain in the New Madrid area has been identified, and uplift of subsurface rock units has also been identified. Analysis of the seismic reflection profile data shows that uplift of the Paleozoic rocks conforms with the surface uplift. This correspondence clearly indicates that the geologic processes that deformed the subsurface strata are continuing today.

Mapping of a trench (see photograph) dug into a shallow scarp within the uplifted area revealed a number of faults with displacements ranging from several inches to 2 feet; one fault had a displacement of



Trenches have been dug across faults that may have been responsible for the 1811-12 New Madrid earthquakes.

more than 9 feet. In this trench, the geologic relationships of sand-blow deposits (inferred to be associated with earthquakes), as well as age dating of the deposits sampled, indicate a recurrence interval of about 600 years for earthquakes during the last 2,000 years. This geologic evidence for a 600-year recurrence interval for major earthquakes is an independent confirmation of estimates of recurrence intervals derived from extrapolation of seismic data. **The subsurface and surface deformation is the first evidence of very young tectonic activity observable at ground level in the Central United States.**

Discovery of an association of earthquakes with an ancient intraplate rift that has had periodic volcanic and tectonic activity has some important implications. By comparison with tectonically active rifts studied in other parts of the world, the structural and seismologic characteristics of the rift in the New Madrid region can be worked out. Identifying the exact extent of the rift is a basis for defining the area in which earthquakes associated with the rift may occur. Because the three largest earthquakes during historic time in the Central United States occurred within the rift, these constraints on their location will have a major impact on earthquake-hazard evaluations.

Meanwhile studies are being actively pursued in the area. Among the important problems concerning the New Madrid seismic zone still to be solved are (1) the details of the origin of the rift, (2) the relationship between the original ancient rift and later development of the Mississippi embayment, (3) the possible relationship of northeast-trending faults in the Kentucky-Illinois mineral districts to faults with similar orientation in the rift, (4) the importance of northwest-trending igneous intrusions and structures in the region to the evolution and seismotectonics of the New Madrid area, and (5) how the stresses in the fault zones interact to control the distribution, intensity, and frequency of earthquakes in the seismic zone.

MAGNITUDE AND INTENSITY: MEASURES OF EARTHQUAKE SIZE AND SEVERITY

Earthquakes can be measured in terms of either the amount of energy they release (magnitude) or the degree of ground shaking they cause at a particular locality (intensity). Although magnitude and intensity are basically different measures of an earthquake, they are frequently confused by the public and by news reports of earthquakes. Part of the confusion probably arises from the general similarity of the scales used to express these quantities. The various magnitude scales represent logarithmic expressions of the energy released by an earthquake. Magnitude is calculated from the record made by an earthquake on a calibrated seismograph. There are no upper or lower limits to magnitude, although no measured earthquakes have exceeded magnitude 8.9.

Intensity, on the other hand, is determined from personal observations of an earthquake's effects on people, structures, and the Earth's surface at a given locality. A number of scales have been devised to rate intensity; the one most commonly used in the United States is the Modified Mercalli Scale of 1931 (see list, this issue) which divides intensity into 12 degrees of severity.

Magnitude

The idea of measuring an earthquake's magnitude based on its seismograph record was introduced in 1935 by Charles Richter, a seismologist at the California Institute of Technology. Although several types of magnitude scales are now in use, they are all related to Richter's original scale and are all measures of a single quantity—the amount of energy released by an earthquake.

Beginning with the logical assumption that, of two earthquakes having the same hypocenter and recorded at the same stations, the larger should write larger seismograms at any one station, Richter measured the amplitudes of many earthquakes in the southern California region that were recorded on identical Wood-Anderson torsional seismometers located throughout the area. Because the instruments were identical, the amplitudes of ground motion were represented identically at each station. Richter constructed a magnitude scale which defined a standard earthquake as one that would produce a trace deflection of 0.001 millimeter on a torsion seismograph located at a distance of 100 kilometers from the earthquake's source. The standard earthquake was given a magnitude of 0. This magnitude scale is expressed by the formula $M_L = \log A - \log A_0$, where M_L is local magnitude, A is the recorded trace amplitude, and A_0 is the amplitude that would be produced by the standard earthquake. Because the scale is logarithmic, an increase of one in magnitude represents a tenfold increase in the recorded amplitude.

Richter's original magnitude scale was designed to measure local earthquakes in the southern California area recorded on the torsion seismometer. The scale could be applied only to earthquakes occurring within about 600 kilometers of the seismograph station. Because of this limitation, Richter and his colleague Beno Gutenberg later developed a scale to measure the magnitude of earthquakes occurring at great distances from the seismograph station. This scale was based upon the amplitudes produced by surface waves with a period of about 20 seconds.

Because surface waves are attenuated with increasing focal depths, deep-focus earthquakes (those occurring more than 700 kilometers below the surface) produce much smaller amplitudes than shocks of the same size occurring at shallow depths. To compensate

for this, a correction factor was devised so that the amplitudes of body waves (those waves that travel from the hypocenter to the seismograph station via the interior of the earth) could also be used to determine magnitude.

From the foregoing discussion, it is obvious that more than one magnitude could be given to a single earthquake, depending upon the method of calculation used. It is important to remember, however, that all magnitudes represent a single quantity—the energy released by the earthquake.

The magnitudes published by the U.S. Geological Survey are averages from several seismograph stations well spaced in azimuth and distance from the earthquake's epicenter. In this way, the influence of local crustal conditions, individual instrument response, irregularities in wave propagation, and human error in measuring amplitudes is reduced.

The formula used by the Geological Survey to calculate surface wave magnitudes is $M_S = \log_{10} (A/T) + 1.66 \log_{10} \Delta + 3.30$, where A is the maximum horizontal surface wave ground amplitude in micrometers, T is the period in seconds, and Δ is the distance in geographic degrees between the epicenter and the recording station. The surface-wave magnitude, abbreviated M_S , is computed for earthquakes in the distance range of 20° to 160° (geographic) for depths less than 50 kilometers. For surface-wave magnitude calculations, the period of the surface wave must be between 18 and 22 seconds.

The body-wave magnitude formula used by the Geological Survey is $m_b = \log_{10} (A/T) + Q(\Delta, h)$ where A is the ground amplitude in micrometers taken from the primary-wave group, T is the period in seconds, and Q , the correction factor, is a function of distance (Δ) and the depth of the earthquake (h). The body-wave magnitude, abbreviated as m_b , is calculated only for earthquakes occurring at distances greater than 5° from the seismograph. For body-wave magnitude calculations, the period of the body wave must fall between 0.1 and 3.0 seconds.

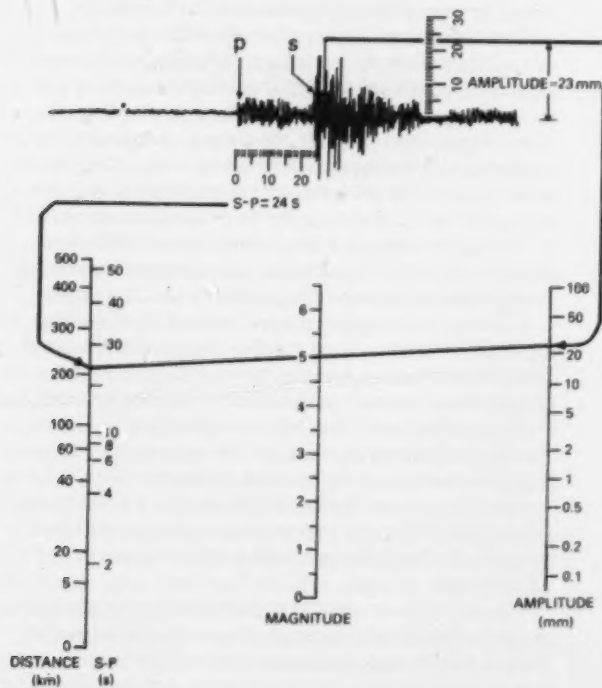
It is important to remember that all magnitude scales are open ended—theoretically they have no limits. Thus, negative magnitudes are permissible because zero magnitude representing the standard earthquake is an arbitrary setting on the magnitude scale.

Calculating the Richter Magnitude of a Local Earthquake

This procedure is reproduced by permission from *Earthquakes: A Primer*, by Bruce A. Bolt, 1978. W. H. Freeman and Co., San Francisco. Copyright © 1978.

Procedure for calculating the local magnitude, M_L :

1. Measure the distance to the focus using the time interval between the secondary (S) and the primary (P) waves ($S - P = 24$ seconds).
2. Measure the height of the maximum wave motion on the seismogram (23 millimeters).
3. Place a straight edge between appropriate points on the distance (left) and amplitude (right) scales to obtain $M_L = 5.0$.



Intensity

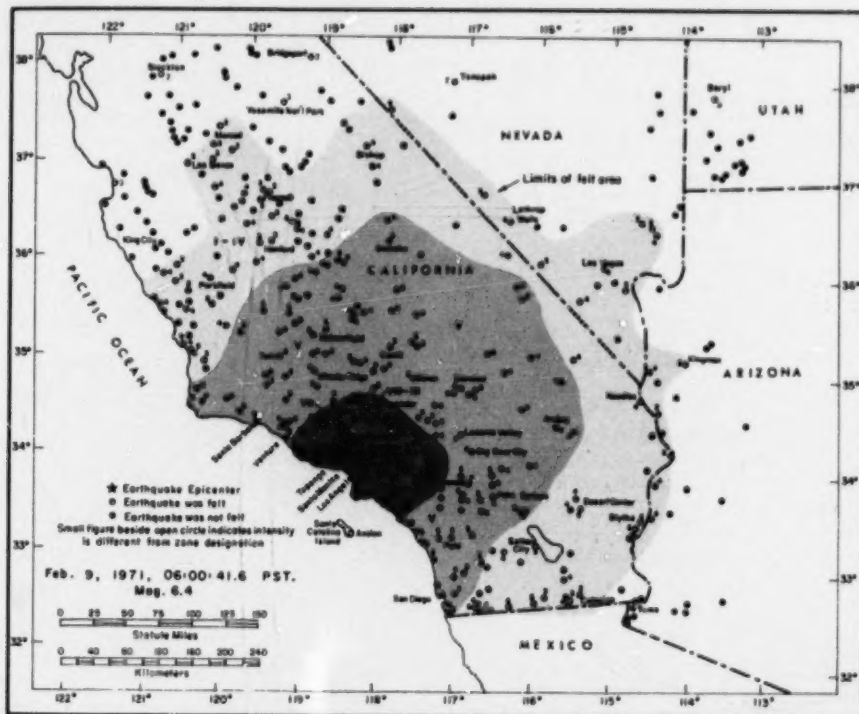
Before the advent of calibrated seismographs, intensity reports were the only data available to the seismologist. Early efforts to determine the size of an earthquake were necessarily based upon personal observations of the severity of the earthquake's effects. Investigators found that characteristic effects of damage and human reactions were very similar for most earthquakes and could be categorized to make comparative studies; the shocks occur at different times in the same or different locations. To facilitate their investigations, early seismologists developed intensity scales that grouped earthquake effects characteristic of each scale value. The first intensity scale to gain wide use was developed in 1883 by M. S. DeRossi of Italy and F. G. Forel of Switzerland. The Rossi-Forel Scale grouped earthquake effects into 10 steps of intensity beginning with I for the least noticeable. This scale is still referred to in descriptions of older earthquakes and is usually identified by an R. F. following the Roman numeral identifying the intensity.

The Rossi-Forel Scale proved to be too peculiar to 19th century Europe to be universally applicable. In 1902, Giuseppe Mercalli of Italy introduced an improved scale bearing his name. The Mercalli Scale also had 10 grades of intensity. This was later increased to 12 at the suggestion of A. Cancani who attempted to correlate intensity with ground acceleration. In 1923, Sieberg, a German seismologist, published an expanded and more detailed scale based on the work of Mercalli and Cancani. Then, in 1931, H. O. Wood and Frank Neumann, who were working at the Caltech Seismological Laboratory in Pasadena, California, proposed a modified and condensed version of the earlier scales developed by Mercalli, Cancani, and Sieberg. Their proposal, appropriately named the Modified Mercalli Scale of 1931, is the intensity scale used most extensively in the United States today. It has 12 levels of intensity expressed as Roman numerals and is printed at the end of this article.

Intensity, unlike magnitude which represents the single quantity of energy release, can have many different values for one earthquake. It can range from "barely perceptible" at the fringes of the felt zone to "total damage" at or near the epicenter. Many factors influence earthquake intensity. Among these are distance from the focus, the earthquake's magnitude, local geology, and the type of fault motion that caused the earthquake.

Because an earthquake's intensity at a particular location must be determined from personal observations at the site during the earthquake, many shocks that occur in remote places and that produce quite high intensities are never evaluated. A magnitude 8 earthquake centered near some remote island in the Pacific might produce far higher intensities than a magnitude 6 earthquake near Los Angeles. Naturally, it is the smaller tremor located near the large city that receives the most attention and is assigned various intensities. The larger shock located at a remote site with few or no inhabitants goes virtually unnoticed by the public.

The Geological Survey is responsible for conducting intensity and damage surveys following felt or destructive earthquakes in the United States. Shortly after a felt or damaging earthquake occurs, a canvass of the affected area is made. Specially developed questionnaires are mailed to volunteer observers located within the estimated felt area. These questionnaires, called *Earthquake Reports*, are filled out by the observers and returned to the Survey's National Earthquake Information Service located in Golden, Colorado. They are then evaluated and each canvassed location is assigned an intensity number. After the numbers have been assigned to the various locations, they are plotted on an intensity distribution map. When all of the intensity data have been plotted, isoseismals can then be contoured through places where equal intensity was experienced. Examples of intensity distribution and isoseismal maps are shown on accompanying illustrations. The completed isoseismal map gives a detailed picture of the earthquake, its effects, and its felt area.



Zoned intensity map of the 1971 San Fernando (California) earthquake.

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
EARTHQUAKE REPORT

Form Approved
OMB No. 42-1170

Please answer this questionnaire and return as soon as possible

1. Was an earthquake felt by anyone in your town near the date and time indicated on the opposite page?

☐ No: Please refold and tape for return mail.

☐ Yes: Date _____ Time _____

☐ AM

☐ Standard time

☐ PM

☐ Daylight time

Name of person filling out form _____

Address _____

City _____

County _____

State _____

Zip code _____

If you felt the earthquake, complete the following section. If others felt the earthquake but you did not, skip the personal report and complete the community report.

PERSONAL REPORT

2. Did you personally feel the earthquake? ☐ 1 Yes ☐ 1 No
Were you awakened by the earthquake? ☐ 2 Yes ☐ 2 No
Were you frightened by the earthquake? ☐ 3 Yes ☐ 3 No
Were you at ☐ 4 Home ☐ 5 Work ☐ 6 Other? _____

Town and zip code of your location at time of earthquake _____

Check your activity when the earthquake occurred:

☐ 7 Walking

☐ 8 Sleeping

☐ 9 Lying down

☐ 10 Standing

☐ 11 Driving (car in motion)

☐ 12 Sitting

☐ 13 Other _____

Were you

☐ 14 Inside or

☐ 15 Outside?

If inside, on what floor were you? ☐ 16 _____

Did you have difficulty in standing or walking

☐ 17 Yes ☐ 18 No

Vibration could be described as ☐ 19 Light ☐ 20 Moderate ☐ 21 Strong

Was there earth noise?

☐ No

☐ 22 Faint

☐ 23 Moderate

☐ 24 Loud

Direction of noise

☐ North

☐ South

☐ East

☐ West

Estimated duration of shaking

☐ 25 Sudden, sharp (less than 10 sec)

☐ 26 Long (30-60 sec)

☐ 27 Short (10-30 sec)

Continue on to next section which should include personal as well as reported observations.

COMMUNITY REPORT

Town and zip code _____

DO NOT INCLUDE EFFECTS FROM OTHER COMMUNITIES/TOWNS

Check one box for each question that is applicable.

- 3a. The earthquake was felt by ☐ No one ☐ 28 Few ☐ 29 Several ☐ 30 Many ☐ 31 All?
b. This earthquake awakened ☐ No one ☐ 32 Few ☐ 33 Several ☐ 34 Many ☐ 35 All?
c. This earthquake frightened ☐ No one ☐ 36 Few ☐ 37 Several ☐ 38 Many ☐ 39 All?

4. What indoor physical effects were noted in your community?

Windows, doors, dishes rattled

☐ 40 Yes

☐ No

Walls cracked

☐ 41 Yes

☐ No

Building trembled (shook)

☐ 42 Slightly

☐ 43 Strongly

Hanging pictures (more than one)

☐ 44 Swung

☐ 45 Out of place

☐ 46 Fallen

Windows ☐ 47 Few cracked

☐ 48 Some broken out

☐ Many broken out

Small objects overturned

☐ 50 Few

☐ Many

Small objects fallen

☐ 52 Few

☐ Many

Glassware/dishes broken

☐ 54 Few

☐ Many

Light furniture or small appliances

☐ 56 Overturned

☐ Damaged seriously

Heavy furniture or appliances

☐ 58 Overturned

☐ Damaged seriously

Did hanging objects or doors swing? ☐ 60 Slightly

☐ 61 Moderately

☐ 62 Violently

Can you estimate direction? ☐ North/South

☐ East/West

☐ Other

Items thrown from store shelves

☐ 63 Few

☐ Many

Continued on the reverse side

6. Indicate effects of the following types to interior walls if any:

Plaster/stucco 65 ☐ Hairline cracks 66 ☐ Large cracks (many) 67 ☐ Fell in large amounts
Dry wall 68 ☐ Hairline cracks 69 ☐ Large cracks (many) 70 ☐ Fell in large amounts

6. What outdoor physical effects were noted in your community?

Trees and bushes shaken 71 ☐ Slightly 72 ☐ Moderately 73 ☐ Strongly
Standing vehicles rocked 74 ☐ Slightly 75 ☐ Moderately
Moving vehicles rocked 76 ☐ Slightly 77 ☐ Moderately
Water splashed onto sides of lakes, ponds, swimming pools 78 ☐ Yes ☐ No
Elevated water tanks 79 ☐ Cracked 80 ☐ Twisted 81 ☐ Fallen (thrown down)
Tombstones 82 ☐ Displaced 83 ☐ Cracked 84 ☐ Rotated
85 ☐ Fallen
Chimneys 86 ☐ Cracked 87 ☐ Twisted 88 ☐ Fallen
89 ☐ Broken at roof line 90 ☐ Bricks fallen
Railroad tracks bent 91 ☐ Slightly 92 ☐ Greatly
Stone or brick fences /walls 93 ☐ Open cracks 94 ☐ Fallen 95 ☐ Destroyed
Underground pipes 96 ☐ Broken 97 ☐ Out of service
Highways or streets 98 ☐ Large cracks 99 ☐ Large displacements
Sidewalks 100 ☐ Large cracks 101 ☐ Large displacements

7a. Check below any structural damage to buildings.

Foundation 102 ☐ Cracked 103 ☐ Destroyed
Interior walls 104 ☐ Split 105 ☐ Fallen 106 ☐ Separated from ceiling or floor
Exterior walls 107 ☐ Large Cracks 108 ☐ Bulged outward
109 ☐ Partial collapse 110 ☐ Total collapse

b. What type of construction was the building that showed this damage?

111 ☐ Wood 112 ☐ Stone 113 ☐ Brick veneer 114 ☐ Other _____
115 ☐ Brick 116 ☐ Cinderblock 117 ☐ Reinforced concrete 118 ☐ Mobile home

c. What was the type of ground under the building?

☐ Don't know 119 ☐ Sandy soil 120 ☐ Marshy 121 ☐ Fill
122 ☐ Hard rock 123 ☐ Clay soil 124 ☐ Sandstone, limestone, shale

d. Was the ground: 125 ☐ Level 126 ☐ Sloping 127 ☐ Steep?

e. Check the approximate age of the building:

128 ☐ Built before 1935 129 ☐ Built 1935-65 130 ☐ Built after 1965

8. Check below any structural damage to

Bridges/Overpasses 131 ☐ Concrete 132 ☐ Wood 133 ☐ Steel 134 ☐ Other _____
Damage was 135 ☐ Slight 136 ☐ Moderate 137 ☐ Severe
Dams 138 ☐ Concrete 139 ☐ Large earthen
Damage was 140 ☐ Slight 141 ☐ Moderate 142 ☐ Severe

9. What geologic effects were noted in your community?

Ground cracks 143 ☐ Wet ground 144 ☐ Steep slopes 145 ☐ Dry and level ground
Landslides 146 ☐ Small 147 ☐ Large
Slumping 148 ☐ River bank 149 ☐ Road fill 150 ☐ Sand fill
Were springs or well water disturbed? 151 ☐ Level changed 152 ☐ Flow disturbed
153 ☐ Muddied ☐ Don't know
Were rivers or lakes changed? 154 ☐ Yes ☐ No ☐ Don't know

10a. What percentage of buildings were damaged?

Within 2 city blocks of your location ☐ None 155 ☐ Few (about 5%)
156 ☐ Many (about 50%) 157 ☐ Most (about 75%)
b. In area covered by your zip code ☐ None 158 ☐ Few (about 5%)
159 ☐ Many (about 50%) 160 ☐ Most (about 75%)

Thank you for your time and information. Refold this card and tape for return mail.

Modified Mercalli Scale of 1931

[Adapted from Sieberg's Mercalli-Cancani scale, modified and condensed]

I. Not felt—or, except rarely under especially favorable circumstances. Under certain conditions, at and outside the boundary of the area in which a great shock is felt: sometimes birds, animals, reported uneasy or disturbed; sometimes dizziness or nausea experienced; sometimes trees, structures, liquids, bodies of water, may sway; doors may swing, very slowly.

II. Felt indoors by few, especially on upper floors, or by sensitive or nervous persons. Also, as in grade I, but often more noticeably: sometimes hanging objects may swing, especially when delicately suspended; sometimes trees, structures, liquids, bodies of water, may sway, doors may swing, very slowly; sometimes birds, animals, reported uneasy or disturbed; sometimes dizziness or nausea experienced.

III. Felt indoors by several, motion usually rapid vibration. Sometimes not recognized to be an earthquake, at first. Duration estimated in some cases. Vibration like that due to passing of light or lightly loaded trucks or heavy trucks some distance away. Hanging objects may swing slightly. Movements may be appreciable on upper levels of tall structures. Rocked standing motor cars slightly.

IV. Felt indoors by many, outdoors by few. Awakened few, especially light sleepers. Frightened no one, unless apprehensive from previous experience. Vibration like that due to passing of heavy or heavily loaded trucks. Sensation like heavy body striking building or falling of heavy objects inside. Rattling of dishes, windows, doors; glassware and crockery clink and clash. Creaking of walls, frame, especially in the upper range of this grade. Hanging objects swung, in numerous instances. Slightly disturbed liquids in open vessels. Rocked standing motor cars noticeably.

V. Felt indoors by practically all, outdoors by many or most; outdoors direction estimated. Awakened many or most. Frightened few, slight excitement, a few ran outdoors. Buildings trembled throughout.

Broke dishes, glassware, to some extent. Cracked windows, in some cases, but not generally. Overturned vases, small or unstable objects, in many instances, with occasional fall. Hanging objects, doors, swing generally or considerably. Knocked pictures against walls or swung them out of place. Opened or closed doors, shutters, abruptly. Pendulum clocks stopped, started, or ran fast or slow. Moved small objects, furnishings, the latter to slight extent. Spilled liquids in small amounts from well-filled open containers. Trees, bushes, shaken slightly.

VI. Felt by all, indoors and outdoors. Frightened many, excitement general, some alarm, many ran outdoors. Awakened all. Persons made to move unsteadily. Trees, bushes, shaken slightly to moderately. Liquid set in strong motion. Small bells rang, church, chapel, school, and so forth. Damage slight in poorly built buildings. Fall of plaster, in small amounts. Cracked plaster somewhat, especially fine cracks chimneys in some instances. Broke dishes, glassware, in considerable quantity, also some windows. Fall of knick-knacks, books, pictures. Overturned furniture in many instances. Moved furnishings of moderately heavy kind.

VII. Frightened all, general alarm, all ran outdoors. Some or many found it difficult to stand. Noticed by persons driving motor cars. Trees, bushes shaken moderately to strongly. Waves on ponds, lakes, running water. Water turbid from mud stirred up. In-caving to some extent of sand or gravel stream banks. Rang large church bells, and so forth. Suspended objects made to quiver. Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary buildings, considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid up without mortar), spires, and so forth. Cracked chimneys to considerable extent, walls to some extent. Fall of plaster in considerable to large amounts, also some stucco. Broke numerous windows, furniture, to some extent. Shook down loosened brickwork and tiles. Broke weak chimneys at the roof-line, sometimes damaging roofs. Fall of cornices from towers, high buildings. Dislodged

bricks and stones. Overturned heavy furniture, with damage from breaking. Damage considerable to concrete irrigation ditches.

VIII. Fright general, alarm approaches panic. Disturbed persons driving motor cars. Trees shaken strongly, branches, trunks, broken off, especially palm trees. Ejected sand, mud, in small amounts. Changes: temporary, permanent; in flow of springs and wells; dry wells renewed flow; in temperature of spring and well waters. Damage slight in structures (brick) built especially to withstand earthquakes. Considerable in ordinary substantial buildings, partial collapse; racked, tumbled down, wooden houses in some cases; threw out panel walls in frame structures, broke off decayed piling. Fall of walls. Cracked, broke, solid stone walls seriously. Wet ground to some extent, also ground on steep slopes. Twisting, fall, of chimneys, columns, monuments, also factory stacks, towers. Moved conspicuously, overturned, very heavy furniture.

IX. Panic general. Cracked ground conspicuously. Damage considerable in (masonry) structures built especially to withstand earthquakes: threw out of plumb some wood-frame houses built especially to withstand earthquakes; great in substantial (masonry) buildings, some collapse in large part; or wholly shifted frame buildings off foundations, racked frames; serious to reservoirs; underground pipes sometimes broken.

X. Cracked ground, especially when loose and wet, up to widths of several inches; fissures up to a yard in width ran parallel to canal and stream banks. Landslides considerable from river banks and steep coasts. Shifted sand and mud horizontally on beaches and flat land. Changed level of water in wells. Threw water on banks of canals, lakes, rivers, and so forth.

Damage serious to dams, dikes, embankments. Severe to well-built wooden structures, bridges, some destroyed. Developed dangerous cracks in excellent brick walls. Destroyed most masonry, frame structures, also their foundations. Bent railroad rails slightly. Tore apart, crushed endwise, pipe lines buried in earth. Open cracks and broad wavy folds in cement pavements and asphalt road surfaces.

XI. Disturbances in ground many, widespread, varying with ground material. Broad fissures, earth slumps, land slips in soft, wet ground. Ejected water in large amount charged with sand and mud. Caused sea waves ("tidal" waves) of significant magnitude. Damage severe to wood-frame structures, especially near shock centers. Great to dams, dikes, embankments, often for long distances. Few, if any (masonry), structures remained standing. Destroyed large well-built bridges by the wrecking of supporting piers, pillars. Affected yielding wooden bridges less. Bent railroad rails greatly, thrust them endwise. Put pipe lines buried in earth completely out of service.

XII. Damage total, practically all works of construction damaged greatly or destroyed. Disturbances in ground great, varied, numerous shearing cracks. Landslides, falls of rock of significant character, slumping of river banks, etc., numerous, extensive. Wrenched loose, tore off, large rock masses. Fault slips in firm rock, with notable horizontal, vertical offset displacements. Water channels, surface, underground, disturbed and modified greatly. Dammed lakes, produced waterfalls, deflected rivers, and so forth. Waves seen on ground surfaces (actually seen, probably, in some cases). Distorted lines of sight and level. Threw objects upward into the air.

Bulletin Board—News in Brief

United Nations Earthquake Prediction Studies

An Ad-Hoc Working Group on International Experimental Sites for Research on Earthquake Prediction, organized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Association of Seismology and Physics of the Earth's Interior, met last summer to discuss ways to improve the theory and techniques of earthquake prediction. The group's task was to provide scientific advice to UNESCO enabling it to carry out a feasibility study and eventually a project proposal for establishing sites for earthquake prediction research.

Some of the group's conclusions and recommendations were as follows:

- Based on seismic activity, the availability of geologic, geotectonic, and neotectonic maps; instrumentation; and accessibility, six regions were deemed to be acceptable for further study—the Peru-Chile border, the Western Hellenic Arc, the North Anatolian Fault Zone, the Meckering area of western Australia, the Beijing-Tienjin-Tangshan area in China, and the Garm-Dushanbe, East Fergana, or Alma-Ata regions of the Soviet Union.
- The sites should be inspected and evaluated by a committee appointed by UNESCO to confirm their suitability.
- UNESCO should approach those Governments to determine their interest in hosting the proposed program.
- The broadest participation will be achieved by having different teams of scientists studying in the same region and applying as many as possible of such available techniques as tilt and strain measurements; study of seismic gaps, swarms, and foreshocks; groundwater monitoring; animal behavior; and time variation studies.
- UNESCO should sponsor a study to draw up guidelines for the formulation, evaluation and communication of future predictions.

More information on the working group's activities can be had from its chairman,

Professor H. Benckhermer,
Institute für Meteorologie und Geophysik,
Feldbergstrasse 47,
6000 Frankfurt,
Federal Republic of Germany.

Minor Eruption of Kilauea Volcano, Hawaii

A minor eruption of Kilauea Volcano occurred on September 28, 1982, which lasted for about 14 hours. The photograph shows the still molten lava forming a roadblock on Crater Rim Drive at the Hawaii Volcanoes National Park. Park rangers allowed visitors to approach the lava, although the heat kept them at a distance. (Laser photograph by Associated Press.)



Earthquakes May-June 1982

By Waverly J. Person,
National Earthquake Information
Service, U.S. Geological Survey,
Denver, Colorado

There were four major earthquakes (7.0-7.9) during this reporting period: two struck in Mexico, one in El Salvador, and one in the Kuril Islands. Mexico, El Salvador, and China experienced fatalities from earthquakes.

In the United States, a number of earthquakes occurred, but only one, in Utah, caused some minor damage.

Alaska

The southeastern part of this State experienced a series of earthquakes beginning on May 2 at 5:36 a.m. AST. The first was a magnitude 5.4 earthquake which was located about 100 miles northwest of Yakutat in an unpopulated area. This shock was followed by a number of smaller earthquakes, some of which were felt at Icy Bay and Yakutat. These earthquakes were located in the same area where a major earthquake occurred on February 28, 1979 (*Earthquake Information Bulletin*, vol. 11, no. 4, p. 146).

Oklahoma

The southeastern part of this State was surprised by a minor earthquake on May 3 at 2:55 a.m. CDT. The magnitude 3.0 tremor was located in Bryan County in the vicinity of Durant, and intensity effects, which registered V on the Modified Mercalli Intensity Scale (MM), were experienced at Durant.

Hawaii

The island of Hawaii was shaken by a number of earthquakes during this reporting period, but most had magnitudes of

less than 4.0. On May 10 at 10:47 a.m. HST, a magnitude 4.2 earthquake occurred on the southwestern part of the island near Makaalia. It was felt on the southwestern part of the island.

The northwest coast experienced earthquakes on May 14 at 6:27 a.m. HST and on May 18 at 5:36 p.m.; these quakes had magnitudes of 4.7 and 4.9, respectively, and were felt strongly on the northwestern part of the island and on Maui. There were no reports of damage.

Montana

The west-central part of Montana experienced a minor earthquake on May 15 at 1:28 p.m. MDT. The magnitude 3.3 quake was located about 50 miles northeast of Missoula in Powell County. Effects (MM V) were noted at Helmville.

New Mexico

A small series of earthquakes occurred in the west-central part of this State. The largest two had magnitudes of 2.8, which occurred on May 18 at 8 seconds after midnight MDT and 12:08 a.m. MDT, and of 2.9, which struck on May 24 at 12:32 a.m. MDT. The earthquakes were located about 9 miles north of Scorro and were felt in the Scorro area.

On May 31 at 3:37 a.m. MDT, a magnitude 2.0 earthquake occurred in the Albuquerque area which was felt mostly in the western part of Albuquerque.

Utah

A magnitude of 4.0 earthquake occurred in the south-central part of Utah on May 24 at 6:13 a.m. MDT. This earthquake was located about 6 miles southeast of Richfield in the Annabella-Glenwood area where slight damage was experienced (MM VI). MM V effects were noted at Elsinore, Koosharen, and Monroe, and MM IV effects, at Aurora and Richfield. The quake was also felt in the areas of Cedar City, Greenwich, Manti, and Sigurd.

California

This State was shaken by a number of earthquakes during this reporting period, but many has magnitudes of less than 4.0. On May 25 at 6:45 a.m. PDT, the southern part of California was shaken by a magnitude 4.1 located in the San Pedro channel about 17 miles south of Long Beach. MM IV effects were noted at Compton, San Pedro, Seal Beach, Surfside, and Torrance. It was felt throughout much of the Los Angeles-Orange County area.

On May 29 at 6:02 a.m. PDT in the northern part of the State, a magnitude 4.2 earthquake occurred about 34 miles southeast of Ukiah. MM V effects were experienced at Cobb and Finley, and MM IV effects, at Geyserville and Kelseyville.

On June 4 at 9:42 a.m. PDT, a magnitude 4.3 earthquake occurred in the eastern part of the State about 9 miles north of Bishop near the Nevada border. It was felt at Bishop, California.

The southernmost part of California was hit by a sharp earthquake on June 15 at 4:49 p.m. PDT. The magnitude 4.8 quake was located about 19 miles south of Palm Springs. MM V effects were experienced at Anza, Coachella, Palm Springs, Pala, White-water, and San Marcos. The quake was felt in other areas of Riverside and San Diego Counties; it was also felt in parts of Imperial, Orange, and San Bernardino Counties. This shock was followed by several aftershocks about magnitude 3.0.

The central part of the State was jolted by a magnitude 4.0 earthquake on June 19

at 3:18 a.m. PDT. The quake was located in the Bear Valley area in the vicinity of the San Andreas fault system about 28 miles southeast of Hollister. It was felt in the areas of Jolon, King City, Monterey, and San Benito.

On June 20 at 11:44 p.m. PDT, the northern part of California experienced a light earthquake. The magnitude 4.1 quake was located about 22 miles southeast of Mount Shasta. MM IV effects were noted at Duns-muir and McCloud. It was also felt at Castella, Mount Shasta, Montgomery Creek, Oak Run, and Weed.

On June 24 at 8:58 p.m. PDT, the central part of the State was shaken by a magnitude 4.0 earthquake located about 22 miles north of Paso Robles. MM IV effects were noted at Coalinga and San Miguel. It was also felt in the areas of Atascaberg, Bradley, Cambria, Paso Robles, Santa Margarita, and Templeton.

Washington

A small earthquake occurred in the southwestern part of this State on May 30 at 10:11 p.m. PDT. The magnitude 2.7 tremor was located about 34 miles north-east of Kelso and was felt at Glenoma and Randle.

On June 4 at 12:45 a.m. PDT and at 9:11 a.m. PDT, two earthquakes occurred about 12 miles northeast of Seattle. The quakes had magnitudes of 2.5 and 3.1, respectively, and were felt in the Avondale-Kirkland-Redmond-Woodinville areas. MM IV effects were experienced at Avondale.

Arkansas

Earthquakes continued in the north-central part of this State with the largest occurring on May 31 at 12:49 a.m. CDT. The magnitude 3.6 earthquake was located about 31 miles north of Little Rock near Enola. MM VI effects were experienced at Enola (*Earthquake Information Bulletin*, vol. 14, no. 4, January-February 1982, p. 148).

Mexico

The southern part of this country was hit by two major earthquakes on June 7 at 12:53 a.m. and 5:00 a.m. local time. The earthquakes had magnitudes of 7.2 and 7.0, respectively, and were centered near the coasts of the States of Guerrero and Oaxaca over 200 miles south of Mexico City. Two people were killed and five people were injured in Pinotela Nacional, Oaxaca, from the second earthquake. Damage occurred in other areas of Oaxaca and in southeastern Guerrero. Some damage was experienced in the Mexico City area from both earthquakes, which were felt strongly throughout southern Mexico. A number of aftershocks followed, but none were large enough to cause additional damage.

China

Sichuan Province in central China was struck by a moderate earthquake on June 15. The magnitude 5.6 earthquake was centered about 250 miles northwest of Chengdu in the Garze area, where 10 people were killed, 5 people were injured, and considerable damage occurred.

Canada

The earthquakes have continued in the New Brunswick area. The largest was a magnitude 4.6 on June 16 at 7:44 a.m. EST. This quake was located about 60 miles north of Fredericton and 50 miles northeast of Presque Isle, Maine. MM IV effects were experienced at Bridgewater, Easton, Fort Fairfield, Monticello, St. Francis, and Stockholm, Maine. The quake was felt in New Brunswick and in other parts of Maine (*Earthquake Information Bulletin*, vol. 14, no. 4, January-February 1982, p. 147).

Connecticut

A series of small earthquakes occurred in the southeastern part of this State. The four largest occurred on June 17 at 4:03

a.m. EDT, 10:14 a.m. EDT, 10:15 a.m. EDT, and 11:29 a.m. EDT. The first two had magnitudes of 2.2 and were followed by two with magnitudes of 3.0 and 2.4. They were located about 22 miles southeast of Hartford in the Moodus area. All the tremors were felt in the Moodus area. The magnitude 3.0 earthquake was also felt at Colchester, Hebron, and Glastonbury.

El Salvador

The southern part of this country was struck by a major earthquake on June 19 at 12:22 a.m. local time. The magnitude 7.0 earthquake was centered about 25 miles south of the capital. At least 16 people were killed, many were injured, and considerable damage and landslides occurred south of San Salvador. In San Salvador, some damage occurred, including damage to the American Embassy. Three people were killed, 40 people were injured, and considerable damage occurred in southeastern Guatemala. The quake was felt at Costa Rica, Honduras, and Nicaragua. A number of aftershocks followed, but none caused additional damage.

U.S. Activity*

Alaska	4
Arkansas	1
California	18
Connecticut	3
Hawaii	18
Maine	1
Montana	1
New Mexico	4
Nevada	2
Oklahoma	1
Utah	1
Washington	3
Total	57

*Felt earthquakes as reported from many sources.

**Preliminary Locations
May-June 1982**

Date	Origin time	Region	Coordinates		Depth (km)	Magnitudes
			Latitude	Longitude		
May 2 —	15 35 58.6	Southeastern Alaska —	60.1 N	141.2 W	13	¹ 5.4 M _L
May 3 —	07 54 50.0	Oklahoma —	34.1 N	96.4 W	5	² 3.0 m _{BLG}
May 10 —	20 47 27.2	Hawaii —	19.2 N	155.6 W	10	4.2 M _L
May 14 —	16 26 32.0	do —	20.0 N	155.9 W	20	4.7 M _L
May 15 —	19 28 18.3	Montana —	47.1 N	113.0 W	5	3.3 M _L
May 18 —	06 00 08.5	New Mexico —	34.2 N	107.0 W	9	2.8 M _L
	06 08 38.4	do —	34.2 N	107.0 W	6	2.8 M _L
May 19 —	03 36 21.0	Hawaii —	19.9 N	156.4 W	1	4.9 M _L
May 24 —	06 32 51.7	New Mexico —	34.2 N	106.9 W	6	2.9 M _L
	12 13 26.9	Utah —	38.7 N	112.0 W	3	4.0 M _L
May 25 —	13 44 30.3	Southern California —	33.5 N	118.2 W	14	4.1 M _L
May 29 —	13 02 25.2	Northern California —	38.9 N	122.8 W	5	4.2 M _L
May 31 —	05 10 40.9	Washington —	46.4 N	122.2 W	11	³ 2.7 CL
	09 37 08.5	New Mexico —	35.1 N	106.8 W	6	2.0 M _L
	17 49 19.9	Arkansas —	35.2 N	92.2 W	5	3.6 m _{BLG}
Jun 4 —	07 44 55.8	Washington —	47.7 N	122.1 W	7	2.5 CL
	16 10 34.1	do —	47.7 N	122.1 W	6	3.1 CL
	16 41 48.3	California-Nevada border region.	37.5 N	118.4 W	26	4.3 M _L
Jun 7 —	06 52 38.5	Near coast of Guerrero, Mexico.	16.6 N	98.2 W	51	⁴ 7.2 M _S
	10 59 40.9	do —	16.6 N	98.3 W	39	7.0 M _S
Jun 15 —	23 24 32.2	Sichuan Province, China —	31.9 N	99.9 W	33	5.6 M _S
	23 49 21.3	Southern California —	33.6 N	116.7 W	12	4.8 M _L
Jun 16 —	11 43 30.0	New Brunswick —	47.0 N	67.0 W	5	4.6 m _{BLG}
Jun 17 —	08 02 38.6	Connecticut —	41.5 N	72.4 W	1	2.2 m _{BLG}
	14 14 20.5	do —	41.5 N	72.4 W	1	2.2 m _{BLG}
	14 14 35.9	do —	41.5 N	72.4 W	2	3.0 m _{BLG}
	15 29 24.4	do —	41.5 N	72.4 W	1	2.4 m _{BLG}
Jun 19 —	06 21 57.4	El Salvador —	13.2 N	89.4 W	83	⁵ 7.0 m _B
	10 17 33.6	Central California —	36.5 N	121.1 W	9	3.9 M _L
Jun 21 —	06 43 38.4	Northern California —	41.2 N	121.9 W	5	4.1 M _L
Jun 25 —	03 58 23.7	Central California —	36.0 N	120.6 W	8	4.0 M _L

¹Richter Magnitude.

²Magnitude from Love waves.

³Magnitude from coda length.

⁴Magnitude from surface waves.

⁵Magnitude from body waves.

Announcements

Meetings

Evaluation of Seismic Hazards and Decisionmaking in Earthquake Resistant Design

This seminar, which is sponsored by the Earthquake Engineering Research Institute, will be held at the MGM Grand Hotel, Reno, Nevada, on February 10, 1983. The goal of the seminar is to identify the various technical issues that arise in the evaluation of seismic hazards for a construction site and to discuss the decisionmaking process that eventually leads to an earthquake-resistant design.

For more information, please contact:
EERI
2620 Telegraph Avenue
Berkeley, California 94704

About EERI

The Earthquake Engineering Research Institute is a national professional society devoted to finding better ways to protect life

and property from the effects of earthquakes. Its objectives are the advancement of the science and practice of earthquake engineering and the solution of national earthquake engineering problems.

International Earthquake Conference

The Conference, which will be held at the University of Southern California, Los Angeles, on February 7-11, 1983, is designed for policymakers and administrators in local government. Plenary sessions and workshops will focus on research, development, evaluation, and implementation of earthquake mitigation measures. Innovative concepts for forecasting, planning and response to emergencies will be presented.

For further information please call:
Councilman Hal Bernson
Conference Coordinator
City of Los Angeles
(213) 485-3343

From the Bulletin Ten Years Ago

The November-December 1972 issue of the *Earthquake Information Bulletin* included items on:

- The Mummy Mountain Observatory, Arizona, operated by Willard Greens;
- Strong-motion instruments installed at Veterans' Administration hospitals;
- A map of vertical crustal movements over the last 100 years prepared by the National Geodetic Survey;
- The 1971 Labor Day earthquake in central California; and
- Earth tides and geyser activity.

Time goes backwards?

In the July-August issue of the *Bulletin*, a photograph on p. 137 showed a trench cut through the San Andreas fault at Pallett Creek, California. The ages of wood matter in the layers apparently showed that the oldest layer (845 years) was at the top and the youngest layer (565 years) was at the bottom. Obviously what was omitted was an A.D. 845 and an A.D. 565.

Reader Survey

Readers, we need your help. So that we can continue to improve your *Bulletin*, will you take a few minutes to let us know your views?

Please list your order of preference.

- Feature articles (such as those on the New Madrid seismic zone, and the magnitude and intensity of an earthquake)
- Short news items (such as those in Bulletin Board)
- Bimonthly earthquakes
- Questions and Answers
- Book Reviews
- General publications

Which do you find to be of no interest?

How do you rate the design and readability of the *Bulletin*?

☐ Excellent ☐ Good ☐ Fair ☐ Poor

How could the *Bulletin* be improved?

☐ More feature articles ☐ Longer articles
☐ Shorter items

More coverage of:

☐ Earthquakes ☐ Volcanoes ☐ Tsunamis
☐ Landslides ☐ Other geologic hazards

What would you like to know more about?

What category are you in?

☐ Professional scientist ☐ Informed layman
☐ Public official

Thank you for helping us to serve you better.

Please send to:

Earthquake Information Bulletin
U.S. Geological Survey
904 National Center
Reston, Virginia 22092
U.S.A.

Publications

General

Earthquake in Campania—Basilicata, Italy, November 23, 1980: Architectural and Planning Aspects. By Henry V. Lagorio and George G. Mader. 1981. 103 p. \$7.50. Available from the Earthquake Engineering Research Institute, 2620 Telegraph Avenue, Berkeley, California 94704.

With funds from the U.S. National Science Foundation, the Earthquake Engineering Research Institute dispatched two researchers to Italy months after the earthquake to study the long-term problems related to architecture and city planning in the reconstruction period. Meetings were held with academicians, engineering and design professionals, and government officials in Milan, Rome, and Naples; field investigations were conducted in the heavily damaged areas; and local officials and reconstruction supervisors were interviewed. This final report summarizes all that was learned in the following areas: damage, implications of damage, and relief efforts; architecture and planning needs; guidelines for undertaking architectural research in foreign countries; and elements of the Italian reconstruction law.

Earthquake-vulnerable Populations in Modern Turkey. By John Kolars. 1982. *Geographical Review* 72. p. 20-35.

The article proposes a method for differentiating the vulnerability to natural disasters of subgroups in a Nation's population and regions within its boundaries so that administrative procedures can be tailored to provide appropriate services and assistance. Although a myriad of variables (for example, regional architectural styles, the availability of doctors, and the number of newspapers and radios) could be determined for any country, the author correlates spatial expressions of population potential, seismicity, and regional accessibility to determine the differential vulnerability of the country to earthquakes. The result of the analysis is a four-point strategy for efficient disaster planning in Turkey: some regions would benefit most from the direct delivery of information through the mass media; certain provinces need better communication between their urban and rural sectors; officials in well-developed rural areas could use more training and more contact with the central government agencies; and a full-scale program to develop emergency planning and response capabilities is called for in most of the rural eastern provinces.

How to Survive an Earthquake: Your Guide and Handbook for Home, Family, and Community Preparedness. By Libby Lafferty. 1982 (revised). 32 p. \$3.75. Order from Creative Home Economics Services (CHES) of California, P.O. Box 1028, La Canada, CA 91011. Special prices are available for bulk orders.

Arguing that the chances of surviving an earthquake are greatly increased if one knows how to prepare for and to respond to a seismic event, this revised edition of the 1978 booklet offers the most current survival information together with expanded more graphic "how to" instructions. The publication provides life-saving suggestions both for the actual duration of the tremor and for the period immediately following. Emergency medical procedures and the storage of food and water receive special attention. The checklists devised for personal and family preparedness are thorough and clear.

Disaster History Film

A retrospective on many of the United States' greatest disasters is given in the American Red Cross' latest film, "Ready for the Worst." Some of the events covered in vivid detail are part of our disaster lore; others, equally as destructive (and instructive) have been lost to memory; for instance, the Peshtigo, Wisconsin, fire in which 1,200 people died on the same day as the Chicago fire. The film traces the sequence of events that led to the Johnstown flood, explains how it was that 6,000 people perished in the Galveston hurricane, and recreates the earthquake in San Francisco.

The film also looks into the future to examine the enormous consequences of an earthquake the size of that in New Madrid in 1811 striking the area today. Because the region is now populated and part of it urbanized, the destruction would be great and terrible.

Copies of the 45-minute film are available in 16mm, ¾ inch videocassette, and ½ inch VHS format. To obtain it, contact:
American Red Cross,
National Headquarters,
17th and D Streets, N.W.,
Washington, DC 20008,
(202) 857-3512.

Earthquake Mechanics. By Keichi Kasahara. 1981. Cambridge University Press. 248 p. \$57.50.

From the publisher's announcement:

"The book describes . . . the contemporary understanding of earthquake origins, and discusses in detail the major contributions to modern theory. Starting from an initial compilation of quantitative views of earthquake origins, the book devotes its principal part to the fault-origin model of earthquakes, with detailed examinations of basic concepts and with examples to assist a realistic understanding of earthquake processes. This is followed by a discussion of physical, rock-mechanical and tectonic problems of earthquake occurrence. The final chapter explains how subjects discussed in previous chapters can be brought together to explore the challenging problems of earthquake prediction and control.

"The book may be used as a textbook for university students in seismology and solid-earth sciences, as well as for engineers who need to understand the essential points of the new seismology. It will also be of considerable interest to engineers and construction workers who wish to increase their knowledge about the cause of earthquakes."

Natural Hazard Risk Assessment and Public Policy. By W. J. Petak and A. A. Atkinson. 1982. Springer Verlag, New York. 300 p. \$46.80.

From the publisher's announcement:

"The book addresses the complex problem of the actions that public policymakers can take to lessen the adverse effects that natural hazards have on people and property. This volume presents a wealth of useful new data on natural hazards—information previously not available in any single source.

"It identifies:

- Stakeholder groups whose interest are bound up in hazard exposure and hazard mitigation.
- Possible public problems.
- The range of technologic and policy options that may be appropriate for solving each problem.

and demonstrates:

- How risk analysis can be applied in defining public problems and assisting in policymaking process.

- How contemporary tools of risk analysis may be applied to investigation of exposure of people and property to nature and other environmental hazards."

Proceedings From the Workshop on Earthen Buildings in Seismic Area. 1981. Available from INTERTECT, P.O. Box 10502, Dallas, Texas 75207. \$35.00, plus \$5.00 foreign postage.

The International Workshop on Earthen Buildings in Seismic Areas was convened in Albuquerque, New Mexico, in May of 1981. The meeting was sponsored by the National Science Foundation, the Office of Foreign Disaster Assistance/Agency for International Development and Appropriate Technology International, and organized by the College of Engineering of the University of New Mexico and INTERTECT. The goal of the workshop were to define the state of the art in earthen building materials and in design and construction methods in seismic regions; to identify research findings and their applicability; and to discuss the transfer of technology across international boundaries. Proceedings have been published that include the 55 papers presented at the workshop, briefing papers on different aspects of earthen construction in seismic areas, research recommendations, and a bibliography.

Seismic Design Guidelines for Highway Bridges. Report no. ATC-6. Applied Technology Council, 2150 Shattuck Avenue, Suite 806, Berkeley, CA 94704, (415) 540-0223. 1982. 200 p. \$20.00. Order from the ATC.

The guidelines, published under contract with the Federal Highway Administration, embody several concepts which depart significantly from existing design provisions. The draft guidelines were tested on the seismic redesign of 21 bridges to assess their practicability and cost. Subsequent changes and a discussion of the redesign results are included in the report. The American Association of State Highway and Transportation Officials is considering adopting the guidelines as part of its Standard Specifications for Highway Bridges.

Assessment of Tsunami Hazard Presented by Possible Seismic Events: Near-Source Effects. By Gerald T. Hebenstreit and Robert E. Whitaker. 1981. 265 p. For availability, contact Paul Krumpke, Office

of Foreign Disaster Assistance, Agency for International Development, U.S. Department of State, 1062 NS, Washington, DC 20523, (202) 632-1834.

Part of a systematic long-range study of tsunami threat in the Pacific Ocean, this report examines three facets of the research and development program as it pertains to the Peru-Chile Trench along the coast of South America. First, earthquake zones capable of generating tsunamis are identified by combining historical seismicity patterns with seismic gap theory. Second, tsunami generation is simulated to examine how waves reach near-source and far-field coastal zones. Third, coastal areas most threatened by tsunamis generated by earthquakes occurring in this zone are identified. The ultimate goal of the program is the reduction of tsunami hazard through education, evacuation plans, and an improved tsunami warning system.

Volcanoes of the World. By T. Simkin, L. Siebert, L. McClelland, D. Bridge, C. Newhall, and J. H. Latter. 1981. Hutchinson Ross Publishing Company, Stroudsburg, Pennsylvania. 240 p. (Distributed by Academic Press, 111 Fifth Avenue, New York, New York 10002. \$19.75.)

This work features a comprehensive and up-to-date regional directory, gazetteer, and chronology of volcanism during the past 10,000 years. It will be a source of information for scientists, historians, and students those interested in the history and effects of volcanoes.

Highlights of the volume:

- 1,343 volcanoes—arranged by region with data on locations, heights, type, known eruptive history, and behavioral characteristics.
- 1,554 eruptions—arranged chronologically with data on duration, explosive magnitude, and volume of products (when known).
- 1,144 volcano names, synonyms, and feature names—arranged alphabetically and cross-referenced.
- 702 references—arranged chronologically by region: a selective guide to the volcanological literature.
- A world map—with volcano locations; a visual index to the data tables.

Volcanoes. By the Editors of Time-Life Books. One volume in the Planet Earth series. Available from Time-Life Books, 541 North Fairbanks Court, Chicago, Illinois. 176 p. \$9.95 plus \$2.00 shipping costs.

This volume combines history with geology to produce an informative yet readable account of the forces which generate volcanoes and the effects that eruptions have had upon human society. Although considerable attention is paid to volcanoes in the Hawaiian Islands and the Cascade Range, the book has an international flavor. Among others, the eruptions of Vesuvius, Mount Fieles, and Hekla (Iceland) are described in vivid detail. Many excellent photographs and illustrations accompany the text. The extensive bibliography is particularly useful for those who have an historical interest in volcanic events.

Mount St. Helens, The 1980 Eruptions: A Bibliography. By Caroline D. Harnly and David A. Tyckoson. Enquiries to C. D. Vance Bibliographies, P. O. Box 229, Monticello, Illinois 61856.

Over 500 books, scientific articles, popular magazines, and government documents have been listed in this bibliography. The contents are arranged under subject headings such as Social and Health Effects, Chemical Studies, and Impact on Industrial and Commercial Ventures. For example, one entry describes how volcanic ash disrupted the functioning of automatic tellers in the fallout area. Brief annotations help to clarify the content of some materials.

China—United States Earthquake Study

As one of the projects authorized in the Agreement on Cooperation in Science and Technology, made in 1979 between the U.S. and China, a delegation of 11 earthquake engineering specialists toured China in the fall of 1980. A summary of their trip and observations has been published by the Earthquake Engineering Research Institute, sponsors of the group. EERI Delegation to the People's Republic of China details what was learned about earthquake-resistant design, construction practices, and research in the People's Republic of China; additionally described are presentations given by the Americans to their Chinese counterparts on the state-of-the-art in the United States.

The delegation visited six cities during the 18 days in the People's Republic of China; Beijing, Harbin, Tianjin, Shanghai, Guangzhou, and Tangshan. Tangshan was of special significance because of its destructive earthquake in 1976; 242,000 were killed, and all industrial production was brought to a halt. The delegates had the opportunity to see some of the ruins and to analyze the structural damage, as well as to observe the reconstruction activities and review the master plan for rebuilding the city.

Theoretical knowledge of earthquake-resistant design is quite advanced in the People's Republic of China, and is commensurate with the theory level in the United States. Actual design and construction practices, however, are less perfected. The People's Republic of China has the universal problem of getting theory into practice, and many helpful suggestions on meeting that challenge were exchanged between the Americans and the Chinese.

Copies of the 125-page report, edited by Roger E. Scholl, are available from:
**Earthquake Engineering
Research Institute,
2820 Telegraph Avenue,
Berkeley, California 94704,
(415) 848-0972.**

Correction

In the *Earthquake Information Bulletin*, 1981, Volume 13, number 6, p 234, it was stated that the Global Digital Seismic Network was operated by NOAA. The Network is operated by the U.S. Geological Survey.

Lifeline Research in Japan.

Research sponsored by the U.S. National Science Foundation and the Japan Science and Technology Agency has produced three recent reports on lifeline earthquake engineering in Japan.

Lifeline Earthquake Engineering Literature in Japan is by Leon R. L. Wang. This is an unannotated bibliography of reports of investigations by Japanese researchers into the effects of earthquakes on tunnels, pipelines, and long-span bridges. All the writings collected herein were done since 1966 and published either in Japanese or in English.

A planned city for science education and research is the subject of *Tsukuba Science City and Its Magnificent Civil and Earthquake Engineering Research Facilities* is by Leon R. L. Wang. Forty-three national research and education institutions have been either relocated from Tokyo or newly established in Tsukuba. The report describes the urban environment, the civil and earthquake engineering facilities, and the problems confronting the new community.

Study of Ground Strains from Strong Motion Array Data for Lifeline Application is by Leon R. L. Wang. This examines the ground displacement and strain data from strong-motion arrays at two sites. The report concludes, however, that for the data from the area to be applicable to lifeline engineering, more strong-motion accelerographs need to be installed no more than 50 meters apart.

Limited numbers of copies of the technical reports are available free from the author at the School of Civil Engineering and Environmental Science, 202 West Boyd Street, Room 334, University of Oklahoma, Norman, Oklahoma 73019. (405) 325-5913.

Deep Trouble

We had many letters pointing out that the geothermal test hole at Newberry Crater, Oregon, featured in the last issue of the *Earthquake Information Bulletin* was rather optimistically described as being 26,730 feet (8,147 meters) deep. This would have been an incredible achievement as well as a world record for a truck-mounted drilling rig.

The correct final depth of the geothermal test hole was 3,051 feet (930 meters) at a temperature of 509°F. (265°C.)

Association of Bay Area Governments (ABAG)

A Guide to ABAG's Earthquake Hazard Mapping Capability	\$ 4.00
Working Paper #16—Detailed Map Information for Selected Existing Urbanized Areas and Landslide Susceptibility Hazard Map Refinement	1.50
Working Paper #17—Using Earthquake Intensity and Related Damage to Estimate Risk of Ground Shaking Damage (Including 5 map plates)	12.00
Working Paper #18—Using Earthquake Hazard Maps to Analyze the Vulnerability of Lifeline System Locations	3.50

Add \$1.00 each for handling
Obtainable from:

ABAG
Hotel Claremont
Berkeley, California 94705
(415) 841-9730

Earthquake Engineering Research Institute Newsletter Subscriptions Available

Libraries, universities, and private firms may now receive the Earthquake Engineering Research Institute (EERI) *Newsletter* and other regularly issued EERI publications such as reconnaissance reports of major earthquakes. In the past, the *Newsletter* was available only to individual members of EERI. The bimonthly *Newsletter* of EERI is informal in format and contains quick preliminary information on worldwide earthquakes. Local newspaper clippings, supplied by EERI members all over the world, often are reproduced and provide another view of events from a nontechnical perspective. *Newsletter* Editor David J. Leeds selects and reproduces articles on earthquakes from a variety of publications in earthquake engineering and related fields. There is a calendar of technical meetings, conferences, and short courses.

In addition to the *Newsletter*, institutional subscribers also receive copies of new publications regularly issued to members. These may include reconnaissance reports for significant world earthquakes and monographs on special topics in earthquake engineering. The number of special publications will vary each year, depending on the number of earthquakes and other factors.

Subscribers will receive all *Newsletters* and special publications which are issued during the

12 months following the subscription entry date. The annual cost is \$150. Three to five more volumes in the popular monograph series are scheduled to appear in 1982.

In addition to the new institutional subscriptions, EERI still has a membership category called Subscribing Member. Subscribing Members pay annual dues of \$250, receive up to 2 copies of all publications, and are listed in the roster of members in the *Newsletter*.

Subscriptions or Subscribing Memberships must be prepaid to:

Earthquake Engineering Research Institute,
2520 Telegraph Ave.,
Berkeley, California 94704

National Oceanic and Atmospheric Administration

The publications and maps listed below are available from the National Geophysical Data Center, NOAA/EDIS, (D92), 325 Broadway, Boulder, Colorado 80303. Make check payable to NOAA/EDIS/NGDC.

Earthquake Seismology

** Available only through National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

SE-3 -----Summary of Earthquake Focal Mechanisms for the Western Pacific—Indonesian Region 1929-1973, March 1977, NTIS No. PB 80207293.	**
SE-6 -----Catalog of Seismograms and Strong-Motion Records, May 1977.	2.00
SE-7 -----Directory of Seismograph Stations (Participating in Seismogram Exchange Through World Data Centers), July 1977, NTIS No. PB 271684/AS.	**
SE-8 -----Survey of Practice in Determining Magnitudes of Near Earthquakes, Part 2, Europe, Asia, Africa, Australia, the Pacific, August 1977, NTIS No. PB 27129/AS.	**
SE-9 -----Survey of Practice in Determining Magnitudes of Near Earthquakes, Part 1, North, Central, and South America, January 1978.	2.00

SE-13	-----Bibliography of Statistical Aspects of Seismicity, August 1978, NTIS No. PB 286139.		KGRD 3	-----Earthquake Data File Summary, May 1978, NTIS No. PB 265445.	..
SE-18	-----Homogeneous Magnitude System of the Eurasian Continent: P Waves, August 1979.	2.00	KGRD 7	-----Catalog of Earthquake Photographs, December 1978.	3.00
SE-20	-----Manual of Seismological Observatory Practice, September 1979.	7.50	KGRD 9	-----Catalog of Seismogram Archives, May 1977.	1.00
SE-22	-----Historical Seismogram Filming Project: First Progress Report, November 1979, NTIS No. PB 80146095.	..	Publication 41-1, Earthquake History of the United States, Revised Edition through 1970 (1973).		5.00
SE-24	-----Historical Seismogram Filming Project: Second Progress Report, August 1980.	3.00	Earthquake History of the United States (1971-78 Supplement) 1979.		2.25
SE-25	-----Directory of World Seismograph Stations Volume I. The Americas—Part 1. United States, Canada, Bermuda.	13.00	Publication 41-2, Earthquake Investigation in the Western United States, 1931-1964 (1965).		3.00
SE-27	-----Catalog of Significant Earthquakes 2000 B.C. -1979, July 1981.	3.00	Earthquake Data Services and Publications.		
SE-28	-----Historical Seismogram Filming Project: Third Progress Report, July 1981.	3.00	Tetrahedron Globe, 1976 (Q)—Earthquake Epicenters of the World.		.20
NGSDC-1	--A Historic Summary of Earthquake Epicenters in and Near Alaska, April 1976.	2.00	Icosahedron Globe, Earthquake Epicenters of the World.		.20
NGSDC-2	--Final Report: An Analysis of Earthquake Intensities with Respect to Attenuation, Magnitude and Rate of Recurrence—Revised Edition, August 1976 (NUREG/CR-1805).	3.00	Significant Earthquakes 1900-1979 map, 1980 (folded).		3.00
NGSDC-3	--An Analysis of Earthquake Intensities and Recurrence Rates in and Near Alaska, October 1976.	3.00	(rolled).		5.00
NGSDC-4	--Reevaluation of Modified Mercalli Intensity Scale for Earthquakes Using Distance as Determinant, January 1978 (NUREG/CR-1804).	5.50			
KGRD 2	-----Catalog of Strong-Motion Seismograph Stations and Records, NTIS No. COM-74-10714.	..			

Earthquake and Tsunami Data Filers

1976 (N-N)	-----World Seismicity and Volcanic Activity in 1975 (global plot).
1977 (R)	-----International Deployment of Accelerometers.
1978 (T)	-----Engineering Data
1979 (U-U)	-----Volcano Map
1980 (N)	-----Earthquake Epicenters of the World (icosahedron globe).
1980 (SE-W)	-----Historical Seismograms
1981 (SP-A)	-----Strong-Motion Earthquake Data.
1981 (SE-C)	-----Significant Earthquakes, 1900-79 (map).
1981 (SE-G)	-----Earthquake Effect File
81-EHB-03	-----Global Digital Seismograph Network Data.
81-EHB-04	-----Tsunami Data Now Available.
81-EHB-05	-----Seismograms from the People's Republic of China.
81-EHB-06	-----Earthquake Data File

U.S. Geological Survey Publishes Book on 1980 Eruptions, Studies of Mount St. Helens

By John E. Findley

A report that summarizes the 1980 eruptions of Mount St. Helens in southwest Washington and the initial results of wide-ranging scientific studies of the volcanic activity and eruptive products has been published by the U.S. Geological Survey, Department of the Interior.

The hard-bound, 844-page volume was designed and edited to be of interest to, and understandable by, a general audience as well as scientists. The 2-inch-thick report is extensively illustrated with maps, charts, and pictures, many of them in color.

"The reawakening of Mount St. Helens volcano in March 1980, and its catastrophic eruption of May 18, surely will rank among the most significant geologic events in the United States in the 20th century," Dr. Dallas L. Peck, Director of the Survey, said in the foreword to the book.

"The debris avalanches, explosive eruption, and associated mudflows and floods resulted in the loss of about 60 lives—including our own David Johnston—and property damage and destruction totaling billions of dollars," Peck said. "We in the U.S. Geological Survey are proud of the role we played in helping to minimize these losses."

The book was dedicated to Johnston, a 30-year-old Survey volcanologist from Menlo Park, California, who was killed at an observation post on a ridge about 6 miles north of the summit of Mount St. Helens when the massive May 18 eruption occurred. The dedication section of the book says that Johnston repeatedly showed the conviction that adequate hazard assessments require accepting the dangers of on-site monitoring of active volcanic processes.

"The volcano-monitoring effort of which Dave was part helped persuade the authorities first to limit access to the area around the volcano and then to resist heavy pressure to reopen it, thereby holding the May 18 death toll to a few tens instead of thousands," the dedication added.

Under the Disaster Relief Act of 1974, the Survey has been delegated the responsibility to provide technical assistance to State and local governments to help ensure that the most timely and effective warning possible is provided for earthquakes, volcanic eruptions, and landslides.

The new book contains more than 60 separate articles by various authors mainly from the Survey but also from other government agencies, universities, and industry. The articles range from such technical subjects as "Petrography and Particle-Size Distribution of Pyroclastic-Flow, Ash-Cloud and Surge Deposits" to more easily understood items such as a summary of eyewitness accounts and a description of "Growth of Lava Domes in the Crater, June 1980–January 1981."

Editors of the book are Peter W. Lipman and Donald R. Mullineaux, both Survey geologists in Denver, Colorado, who were members of the Survey's monitoring and hazard-assessment team in the early weeks of the 1980 eruptive activity. Mullineaux and Dwight R. Crandell were the authors of a Survey report published in 1978 in which they predicted, based on their 20 years of study of Mount St. Helens, that the volcano would erupt again, probably explosively as it did May 18, 1980, and possibly before the end of the 20th century. Crandell also was a member of the Survey's Mount St. Helens team in 1980 but has since retired and works part time for the Survey.

Dr. Peck said that the descriptions by Crandell and Mullineaux and their locations of potential hazards associated with possible eruptions of Mount St. Helens—such as pyroclastic flows, mudflows, and flooding—proved accurate, with few exceptions, in the 1980 eruptions.

"The volcanic hazards assessment by Crandell and Mullineaux provided a key element in reducing hazards to life and property," Peck said.

The magnitude of the landslide and lateral blast on the north side of the volcano on May 18, however, was unprecedented at Mount St. Helens and unexpected said Mullineaux, Crandell, and C. Dan Miller, another Survey geologist in Denver, in their article in the book. The lateral blast extended

about three times farther from the volcano than the largest known previous blast at Mount St. Helens, and it devastated an area that probably is 10 to 15 times larger.

"The May 18 eruption of Mount St. Helens showed that catastrophic events can exceed any known precedent at a given volcano," the geologists said.

The book, *The 1980 Eruptions of Mount St. Helens, Washington*, was published as Survey Professional Paper 1250.

Copies can be purchased for \$35 each from the Branch of Distribution U.S. Geological Survey, 604 South Pickett St., Alexandria, Virginia 22304. Orders must include the identification number (PP-1250) and checks or money orders payable to the U.S. Geological Survey.

Copies can be purchased over the counter at the Survey's Public Inquiries Offices in Spokane, Washington (878 U.S. Courthouse, West 920 Riverside Ave.); San Francisco, California (504 Customhouse, 555 Battery St.); Los Angeles, California (7638 Federal Bldg., 300 North Los Angeles St.); Salt Lake City, Utah (8105 Federal Bldg., 125 South State St.); Denver, Colorado (168 Federal Bldg., 1961 Stout St.); and Reston, Virginia (Room 1C402, U.S. Geological Survey National Center, 12201 Sunrise Valley Drive).

U.S. Geological Survey

Open-File Reports

"Open-file report" is applied by the Geological Survey to results of investigations that are made available to the public outside the formal USGS publication series. These informal reports include manuscript or map copy, basic data, field notes, or other data that are not reproduced and distributed in quantity but are available for public inspection at the indicated depositories.

Most open-file reports are available at cost from the Open-File Services Section (OFSS), Branch of Distribution, U.S. Geological Survey, Box 25425, Federal Center, Denver, CO 80225 (telephone: 303-234-5888).

Check or money, in exact amount for open-file reports ordered, should be payable to U.S. Geological Survey. Prepayment is required. For transmittal outside the United States (except

Canada and Mexico), a surcharge of 25 percent of the bill should be included to cover surface transportation. Specific instructions for ordering are given under each listing.

In the open-file report listings that follow, offices where reports may be inspected are identified by the symbols listed below.

- A Public Inquiries Office, Rm. 106,
Skyline Bldg., 506 2d Ave., Anchorage,
AK 99501.
- Da Library, 1526 Cole Blvd. at West
Colfax Ave., Golden, Colo. (Mail ad-
dress: Stop 914, Box 25046, Federal
Center, Denver, CO 80225.)
- Db Public Inquiries Office, Federal
Bldg., Rm. 169, 1961 Stout St., Denver
CO 80294.
- LA Public Inquiries Office, Rm. 7638,
Federal Bldg., 300 North Los Angeles
St., Los Angeles, CA 90012.
- M Library, 345 Middlefield Rd., Menlo
Park, CA 94025.
- NC Library, Rm. 4A100, National Center,
12201 Sunrise Valley Dr., Reston, VA
22092.
- S Public Inquiries Office, Rm. 678,
U.S. Courthouse, West 920 Riverside
Ave., Spokane, WA 99201.
- SF Public Inquiries Office, Rm. 504,
Customhouse, 555 Battery St., San
Francisco, CA 94111.
- U Public Inquiries Office, Rm. 8105,
Federal Bldg., 125 South State St., Salt
Lake City, UT 84138.

OF 81-0287. *Characteristics of Foreshocks and Short-Term Deformation in the Source Area of Major Earthquakes*. By Peter Molnar. 176 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$22.75.

OF 81-0356. *Regenerate Faults of Small Cenozoic Offset: Probable Earthquake Sources in the Southeastern United States*. By C. M. Wentworth and Marcia Mergner-Keefer. 37 p., 1 oversize sheet. (NC, Da, M; South Carolina Geol. Survey, State Devel. Board, Harbison Forest Rd., Columbia, SC 29210.) Microfiche \$4; paper copy \$4.75.

OF 81-0362. *South Carolina Seismic Program, Seismological Data Report—Selected Events March 1973–December 1977 and Network Events January 1978–July 1980*. By Susan Rhea. 83 p. (NC, Da, M; South Carolina Geol. Survey, State Devel. Board, Harbison Forest Rd., Columbia, SC 29210.) Microfiche \$3.50; paper copy \$10.75.

OF 81-0382. *Seismic Response Mapping of Saint Louis County, Missouri*. By R. W. Stephenson and J. D. Rockaway. 128 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$25.25.

OF 81-0384. A Field Study of Earthquake Prediction Methods in the Central Aleutian Islands. By C. Kisslinger, S. Billington, R. Bowman, J. C. Harrison, S. Ihnen, C. Meertens, J. Pohman, K. Sougstad, and S. T. Morrissey. 54 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$7.

OF 81-0385. Can Animals Predict Earthquakes? A Search for Correlations Between Changes in Activity Pattern of Two Fossorial Rodents and Subsequent Seismic Events. By R. G. Lindberg, D. D. Skiles, and Page Hayden. 38 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$4.75.

OF 81-0386. Water-Level Monitoring Along San Andreas and San Jacinto Faults, Southern California, During Fiscal Year 1980. By P. M. Merifield and D. L. Lamar. 88 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$11.25.

OF 81-0387. Crustal Loading and Induced Seismicity at the Yacambu Reservoir, Venezuela. By C. H. Scholz, Roger Bilham, and David Simpson. 34 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$4.25.

OF 81-0388. Extended Reflection of the San Andreas Fault Zone. By T. V. McEvilly. 27 p., 4 over-size sheets. (NC, Da, M.) Microfiche \$5; paper copy \$5.

OF 81-0397. Investigations of the 8 November 1980 Earthquake in Humboldt County, California. By Kenneth Lajoie and David Keefer. 32 p. (NC, Da, M, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$3.50; paper copy \$4.

OF 81-0399. In-Situ Measurements of Seismic Velocity at 19 Locations in the Los Angeles, California, Region. By T. E. Fumal, J. F. Gibbs, and E. F. Roth. 123 p. (NC, Da, M, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$3.5; paper copy \$15.75.

OF 81-0430. Continuity and Tectonic Implications of the San Simeon-Hosgri Fault Zone, Central California. By R. B. Lealle. 64 p. (NC, Da, M, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$3.50; paper copy \$8.25.

OF 81-0437. Proceedings of Conference XIII: Evaluation of Regional Seismic Hazards and Risk. By W. W. Hays. 251 p. (NC, Da, M.)

Microfiche \$3.50; paper copy \$32.50. (This report will be sold as microfiche only, starting August 1982.)

OF 81-0444. Recent Vertical Movements of the Crust in the Western United States: Reduction and Analysis of Leveling Data and Its Interpretation in Light of Related Seismological Information. By J. E. Oliver. 87 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$11.25.

OF 81-0449. Comparison of Radon Monitoring Techniques, the Effects of Thermoelastic Strains on Subsurface Radon, and the Development of a Computer-Operated Radon-Monitoring Network for Earthquake Prediction. By M. H. Shapiro, J. D. Melvin, T. A. Tombrello, M. H. Mendenhall, P. B. Larson, and J. H. Whitcomb. 84 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$10.75.

OF 81-0454. 1980 Annual of Current Earthquake Literature. By B. S. Hayashida, M. L. Kaufmann, and W. H. K. Lee. 386 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$50.

OF 81-0462. Catalog of Earthquakes Along the San Andreas Fault System in Central California, July-September 1977. By S. M. Marks and L. Fluty. 43 p. (NC, Da, M, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 90012.) Microfiche \$3.50; paper copy \$5.50.

OF 81-0571. Changed Magma Budget Since 1975 at Kilauea Volcano, Hawaii. By Daniel Dzurlin and R. Y. Koyanagi. 48 p. (NC, Da, M, SF, LA.) Microfiche \$3.50; paper copy \$5.75.

OF 81-0668. Displacements on Tectonic Ruptures in the San Fernando Earthquake of February 9, 1971: Discussions and Some Implications. By R. V. Sharp. 18 p. (NC, Da, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$3.50; paper copy \$1.75.

OF 81-0773. Field-Trip Guide to the Quaternary Stratigraphy and Faulting in the Area North of the Mouth of Big Cottonwood Canyon, Salt Lake County, Utah. By W. E. Scott. 13 p. (NC, Da, M, Db, U.) Microfiche \$3.50; paper copy \$1.50.

OF 81-0833. Summaries of Technical Reports, Volume XII—National Earthquake Hazards Reduction Program. B. B. Charonnet, T. R. Rodriguez, and W. H. Selders, compilers. 583 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$75.75.

OF 81-0884. A Study of Earthquake Prediction and the Tectonics of the Northeastern Caribbean: A Continuing Experiment in Two Major Seismic Gaps. By W. R. McCann, A. L. Kafka, and L. R.

Sykes. 27 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$3.50. (Contract report)

OF 81-0937. A Field Study of Earthquake Prediction Methods in the Central Aleutian Islands, Part II. By C. Kisslinger, S. Billington, R. Bowman, S. Ihnen, G. Cruz, J. Pohlman, K. Sougstad, and S. T. Morrissey. 59 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$7.50. (Contract report)

OF 81-0939. Earthquake Maps for Developing Areas in the San Francisco Bay Area. By J. B. Perkins and D. A. Olmstead. 180 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$23.25. (Contract report)

OF 81-0940. A Crustal Deformation Observatory Near the San Andreas Fault in Central California (PB3). By L. E. Slater. 20 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$2.50. (Contract report)

OF 81-0946. Statistical Data for Movements on Young Faults of the Conterminous United States: Paleoseismic Implications and Regional Earthquake Forecasting. By H. R. Shaw, A. E. Gartner, and Fran Lusso. 377 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$50.

OF 81-0955. Locations of Geophysical Instruments and Survey Points Operated under the Earthquake Prediction Element of the Earthquake Hazards Reduction Program, 1981. By T. R. Rodriguez and C. B. Raleigh. 83 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$10.75.

OF 81-0965. Earthquake Hazard Evaluation in the Pacific Northwest. By R. S. Crosson. 72 p. (NC, Da, M.) Microfiche \$3.50; paper copy \$9.25. (Contract report)

OF 81-0984. Seismicity of the Lower East Rift Zone of Kilauea Volcano, Hawaii, 1960 to 1980. By R. Y. Koyanagi. 28 p. (NC, Da, M, SF, LA; USGS, Hawaiian Volcano Observatory, Hawaii National Park, HI 96718.) Microfiche \$3.50; paper copy \$3.50.

OF 81-1120. Lineaments and Fracture Traces, Jennings County and Jefferson Proving Ground, Indiana. By T. K. Greeman. 20 p., 1 over-size sheet. (NC; USGS, WRD, 1819 North Meridian St., Indianapolis, IN 46202.) Microfiche \$4; paper copy \$6.

OF 82-0104. Thermal Springs in the Salmon River Basin, Central Idaho. By H. W. Young and R. E. Lewis. 30 p., 2 over-size sheets. (NC, M; USGS, Box 036, Federal Bldg., 550 West Fort St., Boise, ID 83724.) Microfiche \$4.50; paper copy \$6.25.

OF 82-0156. Effects of Late Cretaceous and Cenozoic Faulting on the Geology and Hydrology of the Coastal Plain Near the Savannah River, Georgia and South Carolina. By R. E.

Faye and D. C. Prowell. 85 p., 8 over-size sheets. (NC; USGS, WRD, 6481 Peachtree Ind. Blvd., Suite B, Doraville, GA 30360.) Microfiche \$7.50; paper copy \$32.25.

OF 82-0180. Proceedings of the Second Joint Meeting of the U.S.-Japan Conference on Natural Resources (UJNR) Panel on Earthquake Prediction Technology, July 13-17, 1981. By D. P. Hill and Keiji Nishimura. 188 p. (NC, Da, M, SF, LA; California Div. Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$3.50; paper copy \$24.25.

OF 82-0205. Seismicity of the Parkfield, California, Region, 1969 to 1979. By G. S. Buhr and A. G. Lindh. 89 p. (NC, Da, M, SF, LA; California Div., Mines and Geol., Room 1341, Resources Bldg., 1416 Ninth St., Sacramento, CA 95814; Ferry Bldg., San Francisco, CA 94111; and State Office Bldg., 107 South Broadway, Los Angeles, CA 90012.) Microfiche \$3.50; paper copy \$11.50.

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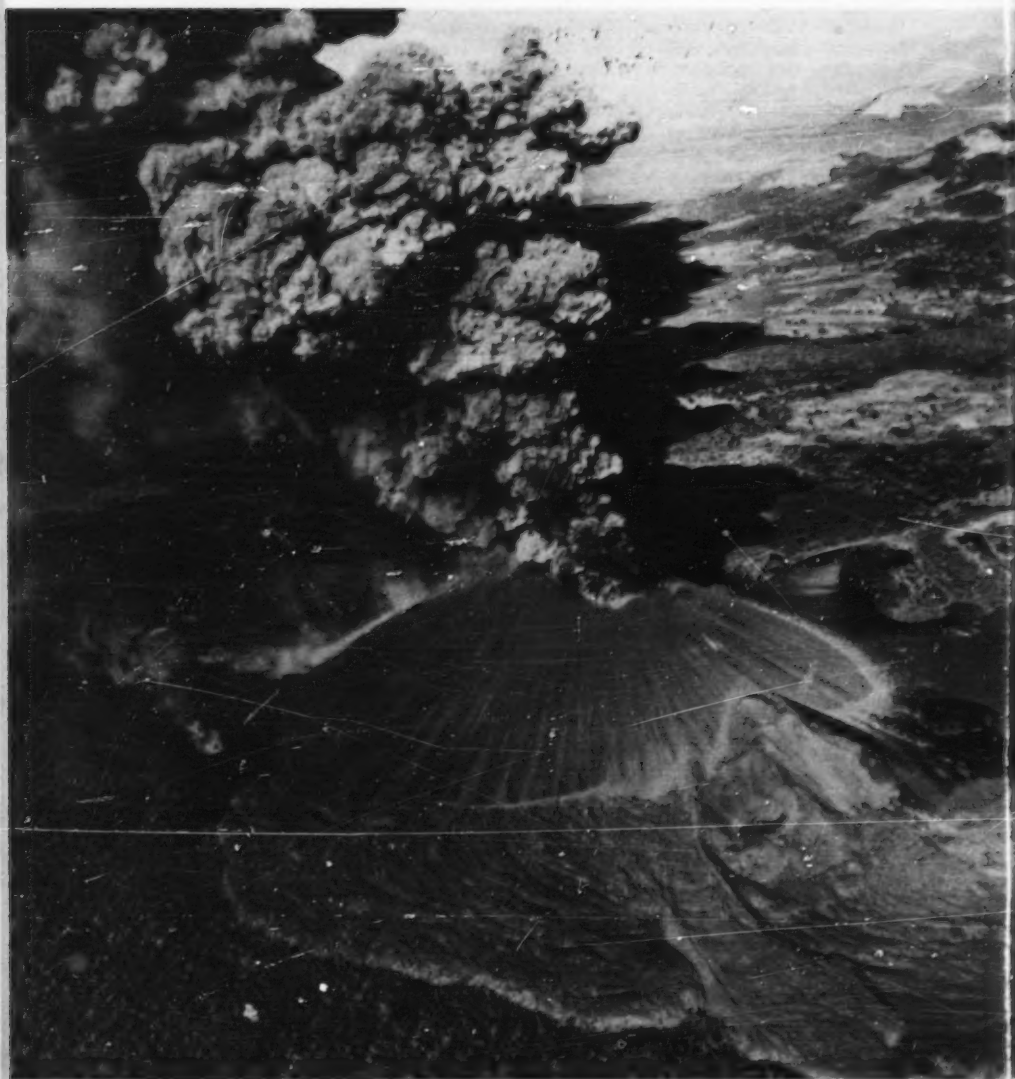
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Eruption of Cerro Negro Volcano (west central Nicaragua) November 1968.

